TECHNICAL BULLETIN No. 511 JUNE 1936

TIMBER GROWING AND LOGGING PRACTICE IN PONDEROSA PINE IN THE NORTHWEST

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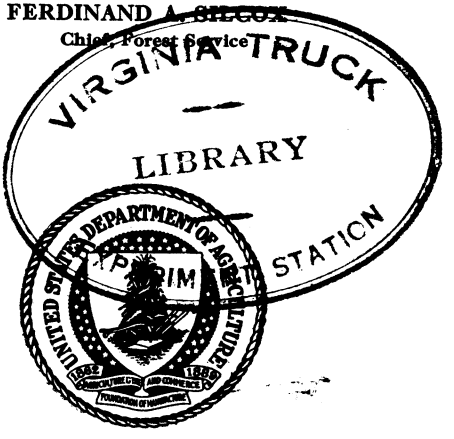

UNITED STATES DEPARTMENT OF AGRICULTURE, WASHINGTON, D. C.

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INTRODUCTION

Forestry on private timberland in the United States is no longer merely a theory or a subject for discussion; it has got down to concrete things in the woods. The conservation clause (art. X) of the code of fair competition for the lumber and timber products industries, approved by the President on August 19, 1933, definitely recognized the need for adopting reasonable and practicable forest measures on private land.

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Timber growing, like the growing of farm crops, is necessarily governed in any region by the soil and climate, by the requirements of the trees themselves, and by economic considerations. Basic information regarding these factors in the growth of ponderosa pine forests of the Northwest has here been brought together for the guidance of those interested. In doing this, the author has drawn not only upon the Forest Service for results of research and experience but also upon the forest schools, the private and State forest agencies, and private operators who have engaged in some form of forestry practice.

This bulletin is the last of a series of 12 publications covering the principal forest regions of the United States. In this bulletin, as in others of the series, the measures proposed are arranged in two general groups. The first group includes the minimum measures needed to prevent timber-producing land from becoming barren. They constitute the least that must be done, even where the owner is primarily concerned with early liquidation of this investment. Such measures will seldom satisfy the landowner who wishes to undertake real timber culture, but they will prevent forest property from becoming a liability to the owner and the community. Reduced to their simplest terms the minimum measures include: (1) Reducing the slash hazard by partial disposal, (2) providing organized protection against fire during and after logging, and (3) insuring some restocking by leaving small, unprofitable trees and safeguarding young growth during logging.

These minimum requirements will preserve some degree of forest growth on cut-over land. They are practical and in fact are now being followed to some extent in a number of cases. Their low cost and their soundness as a matter of good business can scarcely be questioned. To do less than these measures call for would be contrary to public welfare and would constitute a failure of the operator to meet one of the fundamental obligations of land ownership.

The second group of proposed measures constitutes what may be called desirable forestry practice, as far as our knowledge and experience enable us to determine it. They are designed to grow reasonably complete crops of the more valuable timber trees. By building up the area of growing stock on the land, they should bring the property ultimately to its fullest earning power. These measures are addressed primarily to owners who are willing to devote part of their current profits to reserving a thrifty growing stock in the interest of greater profits at the time of future cuts.

In actual practice, it is seldom a question of minimum measures or intensive forestry. Gradations between the two extremes are not only inevitable but desirable and it must be decided for each operation on the basis of expert survey just how far it will be practicable to go. The transitional period often required for the changing over of a forest industry to a sustained-yield basis may involve further modifications of the measures here proposed. While such modification may not meet all the requirements of intensive forestry and may pass many silvicultural problems into the future, it may be amply justified as a means of enabling the operator to reduce carrying charges and losses to a point where he can carry on permanently. Seldom, if ever, will an operator find it most profitable, even with

future growth not considered, to cut clean, as has been the common practice.

Under the code of fair competition of the lumber and timber products industries (1933–35), the lumber industry accepted some degree of forestry as mandatory on all operators. Under this code reasonable rules were prepared for the various timber types and regions. In the northwestern ponderosa pine region adequate protection of timber and cut-over land against fire is the most important single requirement. In any such protection the public should rightly assume a large measure of responsibility. Although the cooperative plan of forest protection embodied in the Clarke-McNary Act, under which costs are shared by the Federal Government, States, and private owners, recognizes this principle, the public share of the burden has so far been rather small. The Forest Service, in its realization of this situation, is committed to work earnestly for a more equitable division of the costs.

Satisfactory returns from forestry cannot be promised in sweeping terms any more than returns from lumber manufacture. The Forest Service, however, has tremendous faith in the commercial promise of timber growing in the United States and earnestly asks forest landowners to investigate the possibilities as applied to their own holdings.

F. A. SILCOX.

GENERAL SITUATION IN THE NORTHWESTERN PINE REGION

THE FOREST AND FOREST TYPES

The ponderosa pine[1] region of the Northwest embraces Oregon and Washington east of the Cascade Range, all of Idaho, and Montana west of the Continental Divide. Within this territory there are approximately 26,500,000 acres of commercial forest land in the ponderosa pine type. About 9,900,000 acres of this are privately owned. Altogether over 2,500,000 acres have been logged up to the present time, and of this close to 90 percent has been private acreage. The present rate of cutting is somewhat more than 100,000 acres a year.

According to estimates made in 1930, the volume of ponderosa pine timber in this region by States amounts to 85 billion board feet lumber tally in Oregon, 22 billion feet in Idaho, 16 billion feet in Washington, and 10 billion feet in Montana. This comprises about 53 percent of all the ponderosa pine in the United States, which is estimated at 250 billion board feet.[2]

The most extensive bodies of ponderosa pine timber are found in eastern Oregon and Washington and in Idaho south of the Salmon River. In northern Idaho and western Montana ponderosa pine occurs in smaller and more scattered bodies intermingled with other

[1] Ponderosa pine (*Pinus ponderosa* Dougl.) is the common name that was adopted in 1932 by the Forest Service and the Western Pine Association for the species that has long been known as western yellow pine. The change was made to overcome the confusion in the lumber trade of western yellow pine with the southern yellow pines, and also to eliminate such misleading trade names for the species as eastern Oregon white pine, California white pine, and Arizona soft pine.

[2] Data from unpublished compilations by the Forest Service.

forest types. Throughout this territory ponderosa pine (*Pinus ponderosa* Dougl.) is the most widely distributed and characteristic tree, occurring both in pure stands and in stands mixed with other species. Its associates are principally western larch (*Larix occidentalis* Nuttall) and Douglas fir (*Pseudotsuga taxifolia* (LaM.) Britt.), and less commonly lowland white fir (*Abies grandis* Lindl.), white fir (*A. concolor* Lindl. and Gord.), and lodgepole pine (*Pinus contorta* Dougl.). Figure 1 shows the geographic location of the commercially important stands.

The two timber types of the region which are of commercial importance are ponderosa pine and larch-fir.

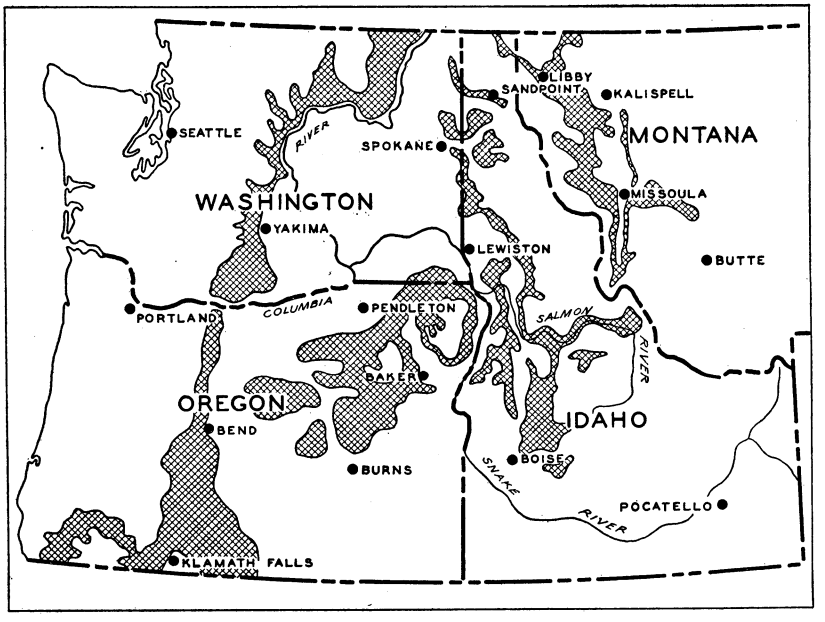

FIGURE 1.—Area occupied by the ponderosa pine forest in the Northwest.

The ponderosa pine type consists of stands in which 50 percent or more of the trees are of that species. The type occurs characteristically on south slopes and flats. In the more gently sloping country of eastern and central Oregon it is often found in pure stands covering many square miles; in eastern Washington and southern Idaho it occupies chiefly south slopes; in northern Idaho and western Montana it occurs on the drier sites within and on the borders of other forest types. Economically, ponderosa pine is the most valuable species and the chief basis of timber operations in the region. Larch, Douglas fir, and the other associated species have a relatively low market value, and as there is much less demand for their lumber than for that of pine, only a small proportion of the stand of these species is logged.

In the eastern part of Oregon, ponderosa pine stands range usually from 12,000 to 18,000 board feet an acre. In Idaho and Washington they average more closely to the lower limit of this range and

in Montana the stands run still less per acre. In the Klamath section of southern Oregon, where the type resembles more the California forest with Douglas fir, lowland white fir, and some sugar pine in mixture, the stands range from about 18,000 to 25,000 board feet an acre.

The larch-fir type which in much of the region is intermingled with the ponderosa pine type, is made up of dense stands containing larch, Douglas fir, white fir, lowland white fir, and some lodgepole and ponderosa pine. In eastern Oregon, particularly in the Blue Mountains, it is very characteristic of north slopes and narrow creek bottoms. In Washington and Idaho it is found on broad, high plateaus as well as on north slopes.

Timber types of the region that are not of commercial importance at present and are therefore not discussed here, are the lodgepole pine, the subalpine, and the juniper.

THE POSSIBILITIES OF TIMBER PRODUCTION

The ponderosa pine forest in many parts of the Northwest has a growth rate and a quality and market value of crop that justify close study of its timber-growing possibilities. In parts of the region, in fact, the conditions are as attractive as in some more favored forest regions, and here there is no reason why the land should not be used to grow timber profitably. In other parts the generally arid climate and poorer sites are conducive to less rapid growth and the timber-growing prospects at present at least are naturally not apt to appeal as strongly to the landowner. The region is a large one, however, and its best land use is the growing of ponderosa pine timber. It is important, therefore, to consider the measures necessary to keep it so employed.

Some idea of the importance of the region for ponderosa pine production may be gained by comparing the regional cut with that of the remainder of the extensive range of this species. According to figures compiled by the United States Census Bureau, the average annual cut of ponderosa pine for the 5-year period 1926 to 1930 was 1,809 million board feet for the northwestern pine region as compared with 1,157 million board feet for the rest of the country.

For the owner of forest land who is considering forestry as a part of his business, certain questions must be answered: What measures in logging, slash disposal, and fire protection are necessary to leave cut-over lands reasonably productive? What additional steps are essential to produce full timber crops? Are these steps practical and what is their cost? What returns in growth of timber can be expected if these steps are taken?

It is the purpose of this bulletin to answer these questions and to discuss the facts, dealing with the life habits of the forest, upon which the answers must be based.

THE IMPORTANCE OF ADVANCE REPRODUCTION

The natural process by which a forest reproduces itself is one of the most important considerations in timber growing. Second growth in the ponderosa pine forest does not spring up as a crop of new seedlings immediately after logging, as is ordinarily the case in

the neighboring Douglas fir and western white pine regions. In the open ponderosa pine stands, seed germinates under the mature trees soon after it falls to the ground. This results in what is called advance reproduction, or young growth on the ground before cutting (fig. 2). A cover of advance reproduction is not the result of one seed crop, but the combined result of a number of years of seeding, germination, and establishment of seedlings. There are several reasons for this long period of regeneration in ponderosa pine. One is that although this species bears a little seed from year to year, good seed years come only at intervals as great as 5 or more years. Another is that the seed furnishes an attractive food for squirrels and other rodents, which in the years of meager seed production consume almost the entire crop. Cone-boring insects are also a cause of reducing the seed supply. But even though successful germination, following a good seed year, may give rise to an adequately stocked cover of seedlings, the severe summer droughts and frosts of this region may in the first 2 or 3 years cause so heavy a mortality among the tender seedlings that only a small proportion will survive. Under these difficult conditions of establishment it requires a number of years—sometimes as much as 20 or 25 years—for the few seedlings which may survive from year to year to make a cover of established young growth that can be counted upon to start a second crop of timber after logging. Such advance reproduction is, however, fairly abundant over most of the region, and the forest, if allowed to do so, reproduces itself almost entirely by this slow method.

It is well to keep in mind that this young growth, developed thus slowly under the mature forest, is already on the ground before logging, as an embryo second crop. Where it is destroyed by fire or other cause, a much longer period is required to establish the second forest crop. Furthermore, the few seed trees that may have been left standing for this purpose are not such effective progenitors, in the face of the difficulties imposed by nature, as the full stand of trees in the virgin forest.

Studies conducted on numerous old cut-over areas in this region showed that as much as 90 percent of the young growth on them was from advance reproduction that had been well established before logging. On comparatively few of the old cuttings examined was the reproduction which had come in subsequent to logging sufficient to make a satisfactory ground cover even many years after cutting.

The regeneration difficulties in the ponderosa pine forest and the vital importance of advance reproduction in perpetuating the timber crop are recognized by other investigators throughout the extended range of this species (*12*, *25*, *28*).[3], [4]

MAIN FACTORS ADVERSELY AFFECTING CONTINUOUS FOREST PRODUCTION

The forces which operate against continuous production are those that destroy or prevent the establishment of young growth. The chief of these is fire. A light surface fire in the virgin forest before logging wipes out the advance reproduction. A broadcast slash fire

[3] Italic figures in parentheses refer to Literature Cited, p. 86.

[4] Reference may be made also to the following: BAKER, F. S. WESTERN YELLOW PINE IN SOUTHERN IDAHO—A COMPILATION OF EXISTING INFORMATION. 37 pp. 1922. [Mimeographed.]

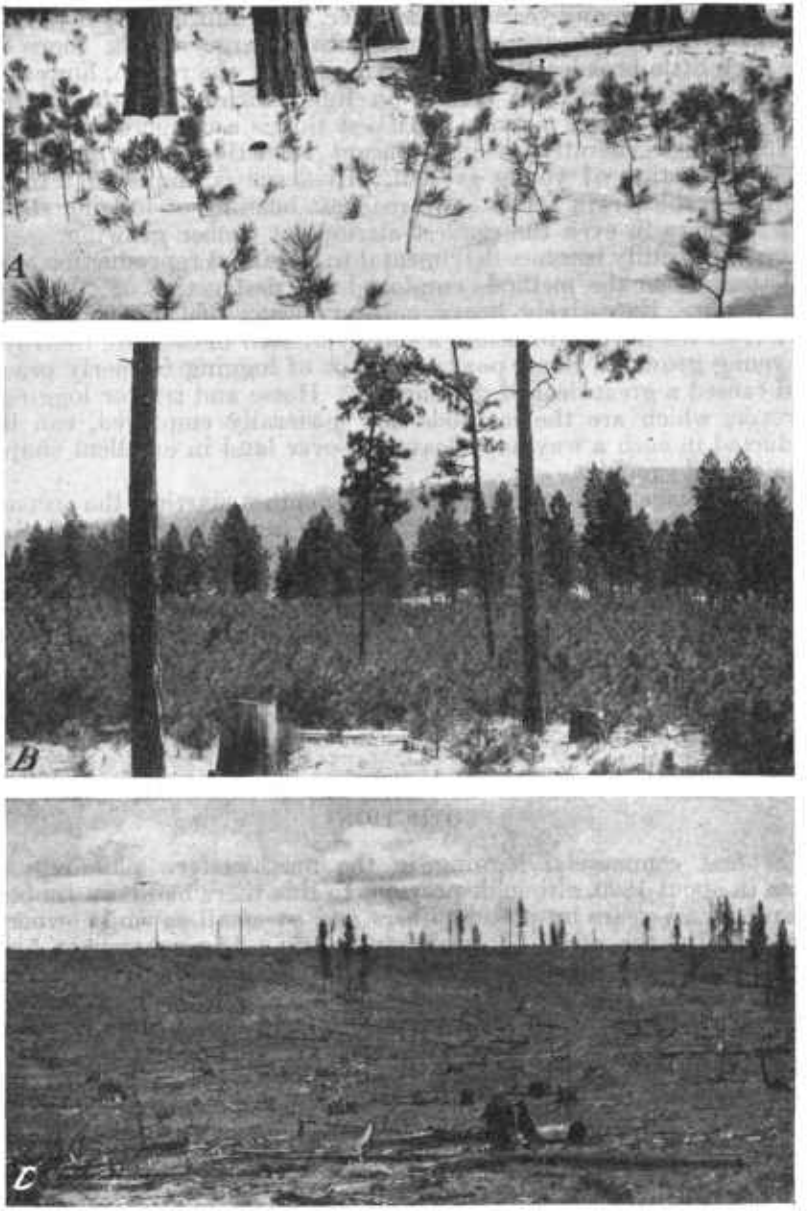

FIGURE 2.—Role of advance reproduction in keeping ponderosa pine forest productive after logging. *A*, Seedlings established in the virgin forest before cutting. This reproduction is mostly under 18 inches tall and up to 15 years old. (F43583A.) *B*, Advance reproduction several years after cutting illustrating its power of recovery. The splendid condition of this area is due to the absence of fire. (F48535.) *C*, Result of broadcast burning of slash with advance reproduction and many small trees destroyed. This waste land will require many decades to become restocked naturally. (F256166.)

after cutting destroys not only the reproduction, but may also destroy the seed trees. In one case the result is seriously to delay regeneration for many years; in the other, the result usually is devastation. Although formerly practiced to a large extent, there is now very little broadcast burning. In parts of the region, however, some timber owners still believe in light burning of the virgin forest as a protection measure. At best this is a dangerous expedient resulting generally in insignificant reduction of hazard and great destruction of young growth. Evidence is ample that light burning in the virgin forest and broadcast burning of logging slash have no place in even the crudest attempt at timber growing.

Logging readily becomes detrimental to advanced reproduction and seed trees when the methods employed are destructive or result in overcutting. Excessively heavy cutting means that too few trees are left on the ground to insure a supply of seed in case fire destroys the young growth. Some power methods of logging formerly practiced caused a great deal of destruction. Horse and tractor logging, however, which are the methods now generally employed, can be conducted in such a way as to leave cut-over land in excellent shape for a second crop.

Grazing sometimes operates seriously against starting the second crop. The damage comes from cropping and trampling of the seedlings to such an extent as to prevent young growth from becoming established. Although damage in the Northwest is not widespread, serious injury to reproduction may and does occur here and there through uninterrupted use of bedding grounds and instances of overstocking and overgrazing of the range.

Occasionally cone insects so greatly reduce the seed supply on large areas as to become a major factor in the difficulties of obtaining reproduction.

THE RESULTS TO DATE OF LOGGING, SLASH DISPOSAL, AND FIRE PROTECTION

The first commercial logging in the northwestern pine region began in about 1890, although previous to this there had been timber cutting for 25 years by placer miners and by small sawmill owners who supplied the needs of local settlements. The subsequent history of ponderosa pine logging presents several events of importance in relation to timber growing.

The first of these was a change from light to heavy cutting. The change was gradual and extended over the decade 1900 to 1910. Previous to this time the timber owner cut only the very best trees and left standing as much as 10 to 25 percent and sometimes more of the volume of the original stand. As cutting became heavier, however, even bull pines[5] down to 10 inches on the stump were logged. Seed-tree conditions on cut-over lands of the early period were excellent, but on the extensive areas logged since 1910 the trees left have been so few and so small as to have little if any effect as seed bearers.

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[5] Bull pine is the name applied throughout this region to young ponderosa pine trees. They have chacacteristically dark bark as compared with the light yellow bark of the older trees. Another name for these young trees is blackjacks, which is prevailingly used in California and the Southwest.

The second event of importance was the enactment of State laws providing for slash disposal. Originally slash was left to decay and disappear naturally. The first slash-disposal laws of the several States became effective in Washington in 1905, in Idaho in 1909, and in Oregon in 1911. All defined slash as a menace or nuisance and provided for its disposal by burning, but without prescribing any special method. Although the intent of the laws was to further forestry, the wording permitted faulty application and execution naturally took the form of broadcast burning. There began a period of destructive burning of cut-over land that lasted 15 years or more and resulted in much devastated stump land. Most of these burned-over lands are now unproductive of forest growth and have little promise of becoming fully productive by natural means for many decades. Thus paradoxically the enforcement of slash-disposal laws became the most serious setback to continuous forest production that the region could have experienced.

Fortunately both the States and the private operators have in late years come to recognize the destructiveness of broadcast slash burning and to take the first steps toward correcting it.[6] In Oregon the forest laws were revised in 1925 to provide, among other things, for partial slash-disposal methods. The forest laws of Idaho were also revised in 1925 with a strong provision for piling and burning, or other adequate disposal under certain restrictions prescribed by the State forester. In Washington it was found that the existing slash-disposal law was flexible enough to permit abatement of the slash nuisance in other ways than broadcast burning. A number of operators in Oregon early began to take full advantage of the new State law to try out partial burning methods such as spot burning and strip burning. Some of these operators included protection of cut-over lands as a part of their slash-disposal plans. Commendable as these efforts are, they are but a beginning and only partially meet the peculiar slash-disposal problem of the ponderosa pine forest. The situation is still serious and is, in fact, one of the very urgent reasons for formulating measures for keeping forest lands productive.

In the way of organized fire protection there was practically nothing outside the national forests until the public and timber owners were aroused to action by the terrible fire losses of 1910. Shortly thereafter State forest-fire laws were enacted, or were strengthened where they already existed, and private fire-protection associations were formed. Compulsory fire patrol came into effect in the several States. The chief object of protection, however, has been to prevent damage to standing timber, and fire protection to this end has reached a high state of effectiveness. Young growth on cut-over land has not been protected for its own sake. Where a watershed has been cut out, the usual procedure has been virtually to abandon it so far as protection is concerned. Thus the general system of protection outside the national forests, except in possibly a few rare cases, has not provided effectively for continuous forest production.

The methods of logging most commonly practiced in the region have only in a few cases caused excessive damage to reproduction

[6] Jacobson (*18*) made the first studies of the slash problem for private operations in this region. His recommendations resulted in the undertaking of less destructive methods, chiefly spot burning and strip burning, on several operations.

and small trees. Horse and tractor logging, the latter having come into use extensively since the World War, have been the most widely used methods and the ones which have done the least damage. Power logging was never employed to any great extent in the northwestern pine territory and has now almost entirely disappeared.

Within the national forests, forestry measures have been practiced since the beginning. Logging on Government timber sales, which began in this region about 1910, has followed a partial-cutting system whereby 15 to 25 percent of the volume of the stand in thrifty trees has been left for a second cut. The timber is carefully marked before cutting, with the object of selecting remaining trees most suitable for producing seed and making increased volume growth. Logging methods which damage young growth and reserved trees are not allowed. Slash is piled and the piles are burned at a season when there is no danger of fire spreading. Intensive fire protection is given to cut-over land as well as virgin timber.

MEASURES NECESSARY TO KEEP FOREST LANDS PRODUCTIVE

WHAT IS MINIMUM PRODUCTIVITY?

Minimum productivity of cut-over land represents a partial stocking of the ground either with reproduction or with small-sized trees, or with both. Just how light this stocking can be may be open to question. For practical purposes, it is here taken to be such stocking as will produce, in a reasonable period of years, the smallest board-foot volume that will justify a logging operation. A minimum cut may conceivably be between 3,000 and 4,000 board feet per acre of merchantable timber. The length of time to attain this volume will depend on the character of the second growth. If it is in the form of advance reproduction, the period will be about 100 years; if small residual trees, it may be 50 years or less depending on the number of small trees left standing.

Where reproduction is the only form, or principal form, of growth present, cut-over land will ordinarily meet this requirement if not more than one-third of the area is blank and two-thirds contains reasonably well distributed seedlings and saplings. These should number at least 200 seedlings[7] per acre, well distributed over the stocked portions of the ground.

Where residual trees are the main form of growth, with little or no reproduction present, cut-over land will meet the requirement of minimum productiveness if it contains at least 20 such trees per acre between 4 and 12 inches or larger in diameter breast high. Trees of this size occur characteristically in groups with rather large stretches of blank ground between, but the openings will in most instances be seeded up gradually to at least a scattering crop of reproduction before the residual trees afford a cut.

[7] These seedlings must be more than 6 inches tall; seedlings under 6 inches are not yet past the period of heavy losses from drought, frost, and other dangers threatening their survival.

Actually economic logging practice favors the leaving of more residual trees than are here indicated. Studies in this region (*7*, *16*), as discussed more fully later on, have shown conclusively that even for those who attach no value to the residual stand there is no margin of profit in cutting small trees. It was found that the minimum size to which logging could be done profitably was 16 inches d. b. h.[8] in a central-Oregon operation and 15 inches d. b. h. in a western-Montana operation. The leaving of trees below the diameter profitable for any given operation will, in most instances, provide at no cost to the operator a nucleus of fast-growing trees as the basis for an early second cut.

Fortunately, advance reproduction is generally abundant in the virgin ponderosa pine timber of the region. With the possible exception of the dry pumice soils of central Oregon, reproduction usually exceeds the minimum here specified. Small trees are not so plentiful over the region as a whole, but where left and protected during logging there will always be a few here and there sufficient to meet the minimum requirements.

Surveys of the stocking of young growth on large areas of private cut-over land in the region, which were made by the Forest Service to determine the suitability of this land for acquisition by the Government, yield some very pertinent first-hand information in this connection. In these surveys 100 percent of the ground was covered; each 2½ acres was examined separately, and averages of stocking were stated by 40-acre units. On 44,324 acres in five large blocks in the Blue Mountains of eastern Oregon, the stocking was as follows: 43 percent of the forties covered with more than 600 seedlings per acre; 30 percent with 250 to 600 seedlings; 21 percent with 50 to 250 seedlings; and 6 percent with less than 50 seedlings per acre. Only established seedlings, 6 inches and taller, were counted, and rating was on a basis of distribution as well as number per acre, the reproduction in groups with large openings between them being rated to a lower classification even though there may have been more than 600 seedlings per acre.

With 73 percent of the ground covered more or less evenly with more than 250 seedlings per acre, as shown by these surveys, the conditions actually existing in the Blue Mountains exceed the requirements for minimum productiveness. In this respect the Blue Mountains represent very closely the conditions throughout the region. The major exception of less satisfactory conditions is that of the section of dry, loose, pumice soils surrounding Bend, Oreg. Here surveys of 55,822 acres of cut-over land, in four blocks, gave a stocking of 45 percent of the ground covered with more than 250 seedlings per acre.

Given the conditions described, it remains to determine what measures and precautions should be taken in the way of fire protection, slash disposal, and better logging practice to leave cut-over lands reasonably productive. The measures arrived at through this study and the facts upon which they are based are discussed in the following pages.

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[8] D. b. h. means diameter at breast height, or 4½ feet from the ground.

THE PROPOSED MINIMUM MEASURES[9]

In order that the reader may have them in mind at the start, the following brief summary of the important measures is given at this point:

SLASH DISPOSAL

The minimum method acceptable is partial disposal by burning slash on strips and spots where the fire risk is high and leaving slash elsewhere. Special fire-protection measures are outlined for the period of 10 or 12 years required for natural reduction of the remaining slash.

Partial disposal is effected preferably by piling and burning on strips 100 to 300 feet wide along roads, railroads, and other lines of fire danger and on areas surrounding camps, landings, engine settings, and similar spots. At least a fifth of the debris should be consumed and not over 20 percent of the cut-over land should be burned over. The strips should divide the area into blocks of about 100 acres in which fires can be isolated.

FIRE PROTECTION

Because of the vital importance of advance reproduction, fire protection must be of the highest standard at all times. Equally as prompt attention should be given to suppressing apparently harmless surface fires in the virgin forest as to fighting fires that threaten merchantable timber. No light burning of the forest or broadcast burning of cut-over land should be permitted at any time.

The general fire-protection system should include lookout and patrol service, fire guards to start suppression, fire-fighting tools and equipment, means of transportation, trails, roads, and telephone lines. In addition, protection during logging and following it should stress prevention measures of the highest standard. These should (1) prevent escape of fire from logging equipment and carelessness with fire by employees; (2) reduce danger at spots of high risk by removal of slash; (3) provide a crew organized fully and systematically for prompt suppression; (4) provide adequate fire-fighting tools and equipment at strategically located points; and (5) provide patrol following trains and watchmen for steam-operated machines.

CUTTING METHODS

If sufficient advance seedlings and saplings are present, the lowest order of productiveness is assured without the leaving of trees in logging. Where such conditions do not prevail, the smaller sized trees must be left. Ordinarily the leaving of all small trees 16 inches d. b. h. and under will insure future productivity. In most cases it will prove more profitable to the operator to leave the small trees than to log them. This practice will not only assure a desirable condition of productivity, but will also provide for a reasonably early second cut.

LOGGING METHODS

Logging methods that will confine destruction of advance seedlings and saplings to less than one-third of the area and damage

[9] Minimum measures and minimum forestry, as used in this bulletin, refer to the lowest order of forestry practice that will secure minimum productivity on cut-over land.

less than 10 percent of remaining trees, will ordinarily meet minimum standards of productivity on cut-over land. The horse and tractor logging methods now being used in the region can meet these requirements. Any developments in tractor logging which would tear up an excessive amount of ground and destroy a large amount of reproduction would obviously not meet minimum requirements. The following precautions should be used to avoid unnecessary damage to young growth: Locate main skidding trails in advance of cutting; confine drivers to the use of these trails; do not allow widespread and unnecessary swamping; do not fell trees into clumps of young growth; wherever practicable fell trees and set chokers in line with skidding direction so as to avoid excessive swinging and consequent injury to reproduction.

SLASH DISPOSAL

Fire does its greatest damage in the ponderosa pine forest when it burns uncontrolled in the mass of slash which results from the logging operation. Examination of numerous cut-over areas has shown that fire which runs in slash either completely destroys the reproduction or so badly damages it that what remains is insufficient to form a satisfactory second crop. Continuous forest production, therefore, requires some sort of reduction and control of the slash menace. Obviously it requires also that this be accomplished by a method which will preserve the young growth.

Several methods of slash disposal have been tried in this territory, including broadcast burning, spot burning, piling and burning, swamper burning, and partial disposal. In the following discussion of these methods the writer has drawn freely upon a comprehensive slash-disposal study which was conducted in Oregon and Washington subsequent to his own field investigations. The results of this study appear in a bulletin by Munger and Westveld (*23*), which is highly recommended to the reader for details of the subject not treated in the present publication.

BROADCAST BURNING

It has already been stated that broadcast burning of slash became the common practice in the Pacific Northwest following the passage of the first State forest-fire laws in the years between 1905 and 1911. Although present efforts on the part of the States and operators are reducing the evil, there is still some broadcast burning.

As a method, if it may be called such, broadcast burning simply means touching a match to the slash as it lies on the ground and stopping the resulting fire when it reaches virgin timber. The removal of the debris being the objective, the operation, to be thoroughly effective, must naturally be performed at a season when the fire will spread readily through the slash. Under such conditions, of course, the slash is completely consumed. But, as will shortly be pointed out by actual examples, reproduction and seed trees are wiped out along with the slash. If the operation, on the other hand, is carried out under conditions when fire will not spread readily, much slash is left unconsumed and the resultant spotted condition of the area includes minimum damage on some portions and complete destruction on others. In this case, much of the slash hazard still

remains and much of the ground is rendered unproductive of tree growth. Moreover, a good deal of the remaining slash is merely scorched, a condition which retards rather than hastens its decay.

The destructive effect of broadcast burning of slash is shown by examinations of a number of cut-over areas on which this method was practiced. Sample strips were run both on burned areas and on neighboring unburned portions of the cut-over land to get the contrast of conditions before and after the fire. Several examples will serve to indicate the degree of damage to young growth and remaining trees.

An area near Sumpter, Oreg., contained before the fire 890 seedlings per acre, which covered 65 percent of the ground. There were also a number of small trees, including 4 seed-bearing trees per acre, between 12 and 17 inches in diameter. Altogether this area had been left in very satisfactory condition after logging. The slash fire, however, killed everything except a few small groups of reproduction and several widely scattered trees. Thirteen years after the fire this area had less than a hundred seedlings per acre and 95 percent of the area was still totally unproductive.

A typical broadcast-burned area near Austin, Oreg., contained before the fire an unusually dense cover of reproduction amounting to 8,000 seedlings per acre which stocked the ground almost completely. Among the scattered small trees there was an average of 1 per acre of seed-bearing capacity. An examination 5 years after the fire showed this area to contain scattered patches of the original reproduction and an average of less than 100 new seedlings per acre. Seventy-five percent of the area contained no reproduction whatever and no trees of seed-bearing size.

A slash-burned area near Cove, Oreg., contained before the fire a great many remaining trees of Douglas fir, white fir, and ponderosa pine and also a very satisfactory cover of reproduction. All but 5 percent of the reproduction was wiped out by the fire and all remaining trees were killed with the exception of about one to each 10 acres. This slash fire killed ponderosa pine trees up to 18 inches and firs up to 20 inches in diameter.

Ten years after the fire about two-thirds of this area had 250 seedlings per acre. Although this amount and distribution of reproduction barely meets the requirements of minimum productivity, it should be stated that this is a better condition than would be expected from the practical absence of seed trees. It is significant to report also that the area was the only one of the kind encountered. The story of what happened here is as follows: Eighty-four percent of the reproduction on the area became established in the first 3 years following the fire and the remainder in the next 3 years. Nothing started thereafter. As one seed tree to 10 acres could not establish this reproduction, it is apparent that the seed came from some such source as a heavy seed crop during the year of the fire, or from trees injured by the fire which lived and seeded for 2 or 3 years before being killed by bark beetles. Secondary attack by insects is often a cause of death of trees which are weakened, but not killed outright by fire. The point to be observed here is that the fire left only a temporary and rather precarious source of seed to give the ground

its present minimum stocking of young growth 10 years after logging. The only seeding possible henceforth is an insignificant long-distance dissemination from the isolated remaining trees.

On five broadcast-burned areas studied in detail by Munger and Westveld (*23*), the slash fire killed all the reproduction on 55, 58, 85, 91, and 94 percent, respectively, of the total acreage of each of the areas. The loss of seed trees and trees that would in time become seed trees varied from 31 to 100 percent for trees under 12 inches d. b. h. and 0 to 79 percent for trees over 12 inches d. b. h.

Only rarely is a broadcast-burned area found on which satisfactory restocking is taking place (fig. 3). Of the total number of areas examined by the author, the one which had restocked best

FIGURE 3.—Idle 20 years after broadcast burning of slash. By no stretch of the imagination could this area, logged and burned in 1909, be described as reproducing satisfactorily in 1929. There is an abundance of willow and other brush, but almost negligible scattering of tree reproduction. (F221286.)

was near Blanchard in northern Idaho. Here all but 96 seedlings per acre were destroyed by the fire, but most of the small remaining trees escaped damage. The surviving seedlings were found chiefly in scattered groups. Of the trees left standing there were six per acre between 10 and 17 inches d. b. h. capable of some seed production. In a period of 16 years following the slash fire, 368 new seedlings per acre became established on this area. These, together with the reproduction which escaped the fire, made a total of 464 seedlings to the acre. Restocking here has been occurring throughout the period since cutting, and the average rate has been 23 seedlings to the acre a year. Although this reproduction is fairly well distributed, there is still 30 percent of the ground unstocked.

There are other serious forms of damage resulting from broadcast burning which are less readily measured than those already discussed. Among these are rapid invasion of brush following the fire, destruction of duff and humus, deterioration and erosion of soil, removal of the sheltering and moisture-conserving shade of small

trees needed to establish new seedlings, and the loss of productivity resulting from many decades of idle land.

It is clear from the examples cited that satisfactory restocking of broadcast-burned areas is not to be depended on. That young growth will escape destruction is still less to be expected. Even where minimum damage results on part of a slash burn, it is common to find complete destruction on another part of the same area. Widespread fire is too powerful and too uncertain in its action to be relied upon in slash disposal where the preservation of reproduction is the primary objective. In view of these facts, broadcast burning is clearly out of the question as a method of slash disposal where the object is continuous forest production.

PILING AND BURNING

Piling and burning has always been the method of slash disposal in national-forest cutting in the ponderosa pine type of this region. The method has been in use about 25 years. Slash is piled as the logging progresses, and the piles are burned at a season of the year, usually late fall, when fire will not spread over the ground. Where the burning is confined to the piles, only 4 to 15 percent of the ground space is burned and the killing of small trees is less than 2 percent, with only rarely the loss of a tree over 12 inches in diameter. The damage by this method of disposal, in fact, is almost negligible. The burned spots are small and are purposely located where reproduction is lacking. Normally the productive capacity of the burned spots will be used in a few years by surrounding young growth and remaining trees. Burning in piles in this way or concurrently with piling, as described on pages 26–27, although expensive, is the most effective method for cleaning up logging debris and the least damaging.

Where the object of the owner is simply to leave cut-over land reasonably productive, it is not believed that this method is necessary. In view of this, the detailed discussion of piling and burning is presented (p. 61) under Measures Necessary to Produce Full Timber Crops.

PARTIAL DISPOSAL OF SLASH

By partial slash disposal is here meant a method whereby logging debris is removed on areas of high risk and left where the risk is low. This means cleaning up slash on strips of varied width along roads, railroads, and other lines of travel, and on areas immediately surrounding engine settings, landings, camps, and similarly frequented spots (*37*). The purpose of the cleared strips and zones is to reduce the chances of fires starting on parts of the area where fire-starting agencies are most prevalent, both during and after logging. Another purpose is to break up the cut-over land into blocks in which to control more readily such fires as do start. As slash will often be left on as much as 80 percent of the ground, intensive protection of cut-over land by patrol and other means during the period required for natural reduction of the debris is an essential part of this system and absolutely necessary to give it security. The intensive-protection feature of partial disposal is described in the section entitled "Protection of Cut-over Land" (p. 32).

Naturally, a proposal which entails the leaving of considerable slash will raise some very definite questions in the mind of the owner who considers it. The most obvious will be:

(1) What has been the experience with fire where slash has been left on the ground?
(2) How long does it take slash like this to decay and disappear as a menace?
(3) What is the hazard, if any, of slash as a breeding medium for destructive insects and fungi?
(4) Can cleared strips be depended upon to help effectively in stopping fires that may start in slash?
(5) Has partial disposal by strips ever been tried and what have been the results of such actual trial?

The first three of these questions can readily be answered from investigations made on numerous old cut-over areas logged before the enactment of forest-fire laws, when the widespread practice of private operators was to leave slash undisturbed on the ground.

REMAINING SLASH IN RELATION TO FIRE

One of the striking facts revealed in studying these old areas was that so large a proportion of them escaped fire. Of 22 areas studied in this connection, only 4 had burned-over portions attributable to slash fires. On one of these, containing about 30,000 acres of the Sumpter Valley cuttings in eastern Oregon, the ground actually burned over up to 1924 amounted to approximately 15 percent of the total area. This condition prevailed on private timberland logged for more than 25 years and traversed by several wagon roads and a wood-burning railroad. Except for a little clean-up of debris along the railroad right-of-way, there was no slash disposal whatever. Neither was any protection given to cut-over land beyond that required to safeguard property and adjoining standing timber.

In this case, the slash-covered ground which burned during the period of 25 years since cutting represents an annual burn of 0.6 percent of the total area. It is significant to note that for an equal period forest fires in this locality burned 0.2 percent of the area of the virgin forest each year. One conclusion to be drawn from this comparison is that slash left on the ground, if given proper protection, is not so uncontrollable a risk in this region as it is commonly believed to be.

Although observations on this and the other areas show that slash left on the ground is a controllable risk, they are not to be taken as an excuse for a laissez-faire attitude toward slash disposal and fire protection. Protection against fires that may be caused by lightning, and the carelessness of man must be provided where certainty of preserving young growth is the objective. To attain assurance of continued productiveness requires a definite plan of action based on a thorough understanding of what happens to untreated slash.

RATE OF DECAY OF SLASH

To determine the rate of disappearance of slash, examinations were made on a number of areas of various ages. The first observation of importance was that most of the needles clinging to the upthrust branches drop off in 2 or 3 years after logging. In 4 or 5 years the

smaller branches become so weakened by decay that they are easily broken off by the weight of snow, and upon falling to the ground are broken into pieces and scattered by cattle and sheep grazing on the area. In 10 or 12 years decomposition has advanced to the point where even the larger branches break off and are scattered to some extent by grazing livestock. About this time the slash is well flattened down and spread about on the ground. Shortly thereafter the bark, unless earlier loosened by insect activity, begins to fall off and become disintegrated. By 25 years after cutting only the tops of trunks and scattered pieces of large limbs are left.

In general, this represents the stages and the period of decay of slash in this region (fig. 4). Owing to variation in climatic and other factors influencing decay and disintegration of slash, the process is a little more rapid in some localities and a little less so in others.

Where the needles and twigs have disappeared and the remaining material has become flattened and scattered on the ground, fires are neither so intense nor difficult to control as in fresh slash, since the whole mass cannot ignite at once as it does when propped up in the air. Although about 25 years is required for the complete disappearance of slash, this is not so important in fire protection as the fact that the period of highest inflammability is passed in 4 or 5 years, and that in 10 or 12 years the slash is no longer a special menace.

INSECTS IN RELATION TO SLASH

The question is often raised whether remaining slash furnishes a breeding medium for destructive beetles, from which these insects spread to young growth, seed trees, and standing timber. An adequate statement of this subject was prepared by F. P. Keen, of the Bureau of Entomology, for the bulletin of Munger and Westveld (*23, pp. 16–17*). This has been reviewed by Keen who states that recent findings do not alter the original presentation:

> Slash serves as a breeding place for two general types of forest insects, beneficial and destructive. The beneficial insects are those which hasten decomposition, or which are predacious or parasitic upon the destructive species. In the destructive group are the bark beetles and bark borers which breed in slash and are also capable of attacking and killing living trees.
>
> The insect menace to living timber from slash-breeding insects is a subject of some controversy among entomologists. However, the findings of the Bureau of Entomology as applied to the type under consideration confirm the observations of the writers on this point, namely, that slash usually does not constitute an insect hazard of any great economic importance to nearby living trees.
>
> In the western yellow pine type of Oregon and Washington only three genera of bark beetles and bark borers need be considered, the Dendroctonus beetles (*Dendroctonus brevicomis, D. monticolae,* and *D. valens*), the pine engraver beetles (*Ips oregoni, I. emarginatus, I. confusus,* etc.) and the pine flatheaded borers (*Melanophila gentilis,* etc.). These are the only insects in the region which breed successfully in logging debris and also attack and kill standing trees.
>
> All of these beetles are strongly attracted to logging areas, where they attack not only the stumps, felled logs, and slash but the standing trees as well. No practicable method of slash disposal will avoid this attractive influence of the cutting areas nor the resultant damage.
>
> The Dendroctonus beetles and the pine flathead borers breed in the stumps and larger felled logs (usually over 6 inches in diameter) both merchantable and cull. As logging progresses the insects attracted to the merchantable logs are removed from the woods, and are no longer a menace. The remaining insects, which have been attracted to cull logs and stumps, do not breed very

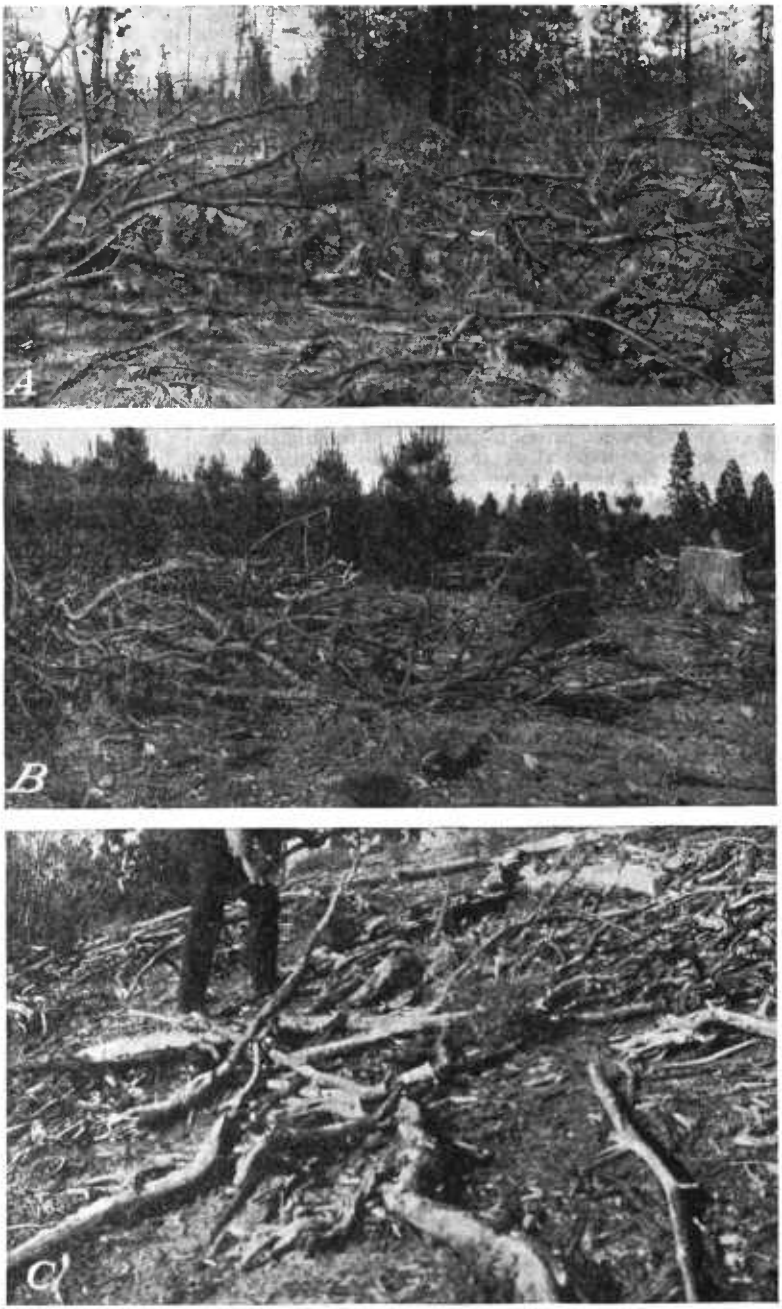

FIGURE 4.—Natural reduction of slash in partial disposal. *A*, Condition 3 years after logging. Practically all the needles have fallen from upthrust branches. Period of highest inflammability is passed (F210418). *B*, Ten years after logging. Finer twigs and branches broken and dropped to ground. (F210436.) *C*, Fifteen years after logging. Even large branches now broken, decayed, and flattened out on the ground (F159810).

successfully in this class of material, and it has been found that the emerging progeny is far below the number produced in standing trees; hence the net result is unfavorable to an increase of beetle population in the logging area. It has been noted frequently that logging areas in which cutting has been continuous are freer from beetle damage than virgin forest areas. Furthermore since these beetles breed principally in material larger than that ordinarily removed as slash, it is obvious that no method of slash disposal entirely removes the material which harbors them.

The engraver beetles of the genus Ips and other small bark beetles of little economic importance breed principally in the smaller material removed in slash disposal. They breed readily and successfully in this material, and frequently their progeny emerges and kills large patches of reproduction, saplings, or the tops or limbs of old living trees. It is generally only for a lack of fresh slash that such trees are selected, as when logging operations are interrupted. Usually a continuous supply of green slash will absorb all of the emerging progeny and forestall any injury to living trees. While the destruction of reproduction may be considerable, the outbreaks as a rule are of short duration and rarely persist for more than one season. J. A. Beal, who has done some recent work on this problem, reports that scattered slash left exposed to the sun breeds very few pine engraver beetles, while shaded slash, such as that in piles, breeds great quantities. Thus the menace to young trees, which these engraver beetles present, suggests scattering the slash rather than placing it in piles, since disposal of the slash by burning usually cannot be accomplished before the beetles have emerged.

A circular of the Bureau of Entomology on this subject (*30*) concludes—"that in the light of our present information, no special methods of slash disposal need be recommended to avoid insect damage to western yellow pine, except in the case of sporadic cutting or when logging operations cease. In such cases infested slash material should be destroyed before the broods of insects emerge."

FUNGI IN RELATION TO SLASH

Although several dangerous species of fungi are found in slash, such as *Trametes pini* (Brot.) Fr., *Fomes laricis* (Jacq.) Murr., *F. pinicola* (Fr.) Cke., *Polyporus schweinitzii* Fr., and *P. ellisianus* (Murr.) Long, they rarely produce fruiting bodies because of the rapid drying out of the host material in this region (*17*). There is, therefore, very little spread of fungus disease from slash to green trees.

On the other hand, fungi play the leading part in causing deterioration of slash, according to a study by Long (*20*), in the Southwest, and observations by J. S. Boyce in eastern Oregon described in an unpublished report of the Bureau of Plant Industry. In this region the two fungi which chiefly attack ponderosa pine slash are western red rot (*Polyporus ellisianus*) and a common dry-rot fungus (*Lenzites sepiaria* (Wulfen) Fr.). The former rot enters the top of the trunk and proceeds into the branches, rotting these for a considerable distance and causing them to drop off. It is a rapid-working rot, which requires a degree of moisture and thrives, therefore, only in the sapwood of the top and in the larger branches that are still attached to the top. *L. sepiaria* is a very slow-acting rot, which enters the smaller branches and works downward toward the larger parts. According to both Long and Boyce, slash with branches attached to the tops, including those thrust upright in the air, rot more quickly by several years than lopped branches lying in close contact with the ground.

EFFECT OF REMAINING SLASH ON REPRODUCTION

Another question is whether remaining slash destroys an appreciable amount of advance reproduction, or retards its development,

and also whether it prevents the starting of new reproduction. The examination of cut-over areas revealed only a very slight and negligible damage of this sort. On one area a series of sample plots was taken to determine the actual extent of this damage. The area had been clean cut 6 years previously, leaving a mass of slash which in spots was exceedingly heavy. There was a dense stand of reproduction which almost completely covered the ground. Although many seedlings had been bent over and covered by the slash, less than 4 percent of all the reproduction on the sample plots seemed to have been killed by the slash. The bent-over seedlings had largely recovered and were growing up through the slash.

Munger and Westveld reached similar conclusions in their later study of the effect of slash on reproduction (*23*). They found that slash killed some of the reproduction and injured some, but left most of it undisturbed, the size of the seedlings and density of the slash determining the amount of damage. Seedlings below 6 inches in height suffered heavily, whereas those over 3 feet usually escaped injury. Their observations on sample plots showed that from 1 to 23 percent of the reproduction on various areas had been covered and killed by the slash. Observations agree that slash left on the ground does not cause enough damage to reproduction to interfere seriously with the starting of the second crop.

EXECUTION OF PARTIAL DISPOSAL METHOD

The foregoing paragraphs give the facts that have been learned regarding slash left on the ground without systematic treatment. What now may be expected in the way of security from fire where part of the slash is removed in planwise fashion and the remainder is given special protection? Fortunately, there have been in recent years several noteworthy trials of partial disposal in which a few operators in Oregon and California pine timber have removed slash on strips, have left it elsewhere, and have applied in varying degree special measures of protection to cut-over land.

ACTUAL TRIALS OF PARTIAL DISPOSAL

The Fruit Growers Supply Co. of California furnishes an outstanding example of partial disposal of slash (*2*).[10] The area covered in the first 5 years (1926–30) included 33,000 acres and contained 146 miles of cleared strips (fig. 5). The strips were made 100 feet wide, occupied about 10 percent of the area, and divided the cut-over ground into blocks of approximately 100 acres. Plowed fire lines were run on both sides of the strips. Two methods of cleaning up slash on the strips were tried—uniform piling and burning and a combination of spot firing with piling and burning. In the latter case accumulations of slash that would burn clean were fired broadcast and intervening scattered slash was piled and burned. As the company desired the strips to be as bare as possible of all inflammable material, including reproduction and undergrowth as well as slash, it favored the second method. Burning was done

[10] The reference cited has been supplemented by later data in the following article: WOODBURY, T. D., BURNETT, O. P., and EDMONDS, M. W. PROGRESS REPORT ON EXPERIMENTAL USE OF FIRE-BREAKS WITHIN NATIONAL FOREST TIMBER SALE AREAS IN THE CALIFORNIA REGION. 76 pp. 1935. [Multilithographed.]

FIGURE 5.—Cleared strips in partial slash disposal on a California operation. *A*, Strip cleared of all trees and undergrowth; *B*, strip cleared of all undergrowth, but containing reserved trees; *C*, strip on which railroad grade was converted into a protection road. (Photos by courtesy of Fruit Growers Supply Co.)

carefully during safe periods and little fire escaped from the strips. Intensive protection facilities consisted of a fire warden, patrolmen, tool caches, pumps and hose, tank cars, fire-fighting equipment on locomotives, donkeys, and jammers, and telephone communication with Forest Service lookouts. Logging crews of all the camps were organized for suppression duty in case of fires. Eighty-three miles of special roads, many of them converted railroad grades, rendered the cut-over area accessible by automobile for patrolmen and suppression crews. The plan contemplated regular replowing or dragging of the fire lines flanking the strips every 3 or 4 years.

This trial of partial disposal has been in effect 7 years and has survived several bad fire years, including 1929, with only negligible loss and an excellent record of fire control. A report of the company forester for 1929 gives two notable instances in which the strips helped to stop fires. The report of a fire on October 9, 1926, reads as follows:

> At the time of the outbreak of this fire, a terrific wind from the southwest made it necessary to discontinue logging operations for the day. The entire logging crew was then organized to suppress this serious outbreak. Men were stationed on the lane and behind the lane, and in this way they were able to put out all sparks that crossed the lane. When the fire burned up to the fire lane it went out because of lack of further fuel. The flanks were controlled by skid trails that were opened up for such an emergency. Very little trail building was required to stop this fire.

On May 26, 1928, a fire occurred under similar heavy wind conditions. Sparks were thrown ahead and direct attack was impossible. The crew was stationed along the strip ahead of the fire to put out all sparks that crossed it. Here also the fire was stopped when it reached the cleared strip.

In central and eastern Oregon, modified forms of partial disposal and protection of slash have been tried by several large operators with reasonably satisfactory results. The record of one company for a period of 6 years was 60 fires covering a total of only 129 acres. Most of the fires were held to very small size, and the largest reached only 60 acres. The area cut over during the period was about 50,000 acres.

These examples are eloquent testimony of the adequacy of partial disposal as a minimum forestry measure. In carrying out the method it will be necessary to consider certain principles governing the location and width of strips, size of blocks, and manner of disposing of slash on the strips. Execution of the various steps, however, should be adapted to circumstances and not governed by fixed rules.

STEPS IN CARRYING OUT PARTIAL DISPOSAL METHOD

As one of the objects of the cleared strips is to reduce the chances of fire starting through human agencies on traveled parts of the area, strips should logically be located along roads, railroads, trails, chutes, fishing streams, and other lines of danger. Additional strips will be needed to subdivide the area into blocks in which such fires as start may be isolated. In locating these latter, advantage can usually be taken of ridges, meadows, and other natural features, where the small amount of slash will often serve to reduce the cost of disposal and to increase the protection possibilities.

As the location of strips will be controlled largely by existing travel routes and topographic features, the blocks which they form will necessarily vary in size. Ordinarily they should not greatly exceed 100 acres. In more open ponderosa pine stands where there is little slash on the ground they may be larger, but in pine and fir mixtures where there is heavy slash together with considerable young growth and small trees, even smaller blocks may be desirable to give full security.

Strips may vary in width with differences of slope, prevailing winds, distance to which sparks will be thrown, and other conditions, but in general they should not be much less than 100 feet wide. A maximum width of approximately 200 feet along railroads and other main routes of travel is desirable.

The manner in which slash is cleaned up on the strips is an important consideration. At one extreme is broadcast burning and at the other piling and burning. By some people broadcast burning is supposed to produce the ideal firebreak, a strip bare of all inflammable material. Actually, as has been shown, such a result is rarely attained. When weather conditions are safe for its use, broadcast burning consumes the massed debris, but will only flash through saplings, underbrush, and scattered slash, and thus leave charred residual material as fuel for later fires. On the other hand, if the weather is such as to permit a hard burn there is always the greatest danger of fire escaping from strips. At best, broadcast burning wipes out reproduction and remaining trees on the strips and removes a portion of the land from productiveness. Piling and burning, on the other hand, definitely cleans up all slash on the strips with minimum damage and minimum loss of productivity. Between the two extremes lies a combination of spot burning with piling and burning. By this method dense accumulations of slash are burned as they lie and intervening scattered slash is burned in piles. A complete clean-up is attained with only moderate damage and at low cost.

Each method of removing slash on the strips may have its place under different conditions, but for general use as a minimum protective measure the combination of spot burning with burning in piles is recommended. Narrow fire lines cleared to mineral soil are desirable to guard the sides of strips, no matter what the method of burning. Although they may not be needed during the process of burning in piles, they will give added security to the strips in their later service as firebreaks.

There is a question as to the degree to which the strips should be made fireproof. If all the saplings, underbrush, and slash have been removed and the ground is burned bare, the strip will naturally be more effective in preventing fire from creeping across it than if only about 10 percent of its surface has been burned, as with piling and burning slash alone. There are, however, certain factors an operator should consider before deciding upon complete, as compared with partial, fireproofing of strips.

In the first place, cleared strips cannot in themselves be depended on to stop a fire. Sparks will jump across them on windy days. In any case, therefore, a special protection organization is necessary to detect and fight fires through use of the strips as vantage points.

This being so, no great advantage is gained by having the grass, herbaceous growth, and reproduction burned off, so long as the inflammable slash material has been removed and fire lines have been plowed on each side of the lane. A narrow line made with a plow or grader is sufficient to stop the creeping type of fire. Moreover, to keep the strip bare of grass and shrubbery growth would mean reburning and other strip-maintenance work at periodic intervals. Further, strips that are cleared of slash but not burned bare will retain just that much more cut-over land in productivity. Although this may not amount to more than 20 percent, it becomes a factor when added to other unproductive parts of the cut-over land caused by natural blanks and understocking of reproduction or remaining trees.

It is evident, therefore, that the purpose of strips in partial slash disposal may be effected without burning them bare. Where they contain dense patches of underbrush and saplings that would greatly accelerate the run of accidental fire these should be cut and burned in piles along with the slash. It is not believed to be necessary, however, permanently to maintain strips in this cleared condition. Their main purpose is served during the first decade of high slash hazard. After the decay of the logging debris there is no more need of cleared strips under partial disposal than there is on cut-over land where all the slash has been piled and burned. In other words, a network of fire lanes, although a highly desirable feature of any intensive protection system, is not a distinctive requirement of partial disposal after the slash menace has disappeared.

SNAGS IN RELATION TO PARTIAL SLASH DISPOSAL

The question of what should be done with snags is intimately involved with slash disposal. It is well known that burning snags will throw sparks considerable distances and set spot fires in advance of the main fire. Thus they constitute one of the risks in case of fire on cut-over land. In some forest regions this is held to be so serious as to require complete felling of snags on cut-over areas. There is reason to believe, however, that the snag risk is not great in the pine territory of the Northwest.

So far as the old cut-over areas of the region are concerned, the leaving of snags has given as little cause for alarm as has the leaving of slash. A noteworthy observation in the study of cut-over areas, in fact, has been the scarcity of standing snags, indicating their early fall following logging. In this connection, an investigation conducted by F. P. Keen of the Bureau of Entomology yields some definite facts regarding the time required for the natural falling of trees killed by bark beetles (*19*). On 640 acres of virgin ponderosa pine timber, which were examined annually for 9 years, the trees killed by beetles each year were tagged and observed till they fell to the ground. The records of 3,015 snags kept in this way showed a consistent and rapidly increasing rate of fall year by year following the year of death. Of trees dead 5 years only 15 percent, roughly, had fallen to the ground, but of those dead 7 years 50 percent had fallen, and of those dead 9 years 75 percent.

In the case of cut-over areas, the snags standing at the time of logging obviously will already have been dead, probably for at least

5 years. Therefore, as many as three-quarters of the snags may be expected to fall in the first 5 years after logging. The time of fall may in many cases be hastened by the increased exposure to wind.

Unfortunately, although snags fall to the ground in a relatively short time, the period during which they stand coincides with that of the highest inflammability of slash. For this reason some snag felling on spots of high risk is a desirable measure. The portions of cut-over land that fall into this category will not be great and will usually consist of railroad rights-of-way and certain other spots where there is extreme likelihood of fire starting or of burning snags throwing sparks great distances. An example of the latter would be a concentration of snags on a windward, upper slope where they could through fire over the ridge top into an adjoining drainage. In this connection, it is well to keep in mind that Douglas fir and white fir snags rot rapidly at the top, break off, and leave inflammable stubs standing; whereas pine boles and tops remain sound but fall to the ground because of the rotting of the snag at the roots.

On cleared strips, except along railroads, snags are less of a menace standing than after they have fallen crisscross over the strips, creating fuel that will carry fire across the cleared ground. To avoid the annoyance and cost of annual maintenance work, all snags on the strips should be felled and removed at the start. The removal can be effected cheaply by hauling them to the side of the strip by tractor. The cost of snag disposal will ordinarily be less than 2 cents a thousand board feet of timber cut if they are sawed down and less than half a cent a thousand if they are pushed over with a tractor and a pair of slip-tongue wheels (*1*) and even less if they are burned down at a safe season of the year as described by R. B. Weaver (*34*). As for strips along rights-of-way, operators will want to fell snags on them in any case as a necessary measure for efficient operation of the transportation system. The recommendation, therefore, is to fell snags on the strips and in certain restricted spots as here indicated.

SUMMARY

With the proposed, systematic clean-up of slash along strips of high risk, the segregation of the cut-over area into blocks by such strips and with special protection for 10 or 12 years, the possibilities of fires starting will be reduced and the opportunities for suppressing those that do start will be greatly enhanced. Next to piling and burning all of the slash, it is believed that this method gives more assurance of safely accomplishing the objective than any other. Whether the method here described will necessarily prove to be the final word in slash disposal for continuous forest production will have to be determined by further trial and experimentation. So far as present knowledge goes, however, partial disposal plus intensive protection appears to be the most practicable measure for handling slash where intensive forestry is not to be practiced. The method is one which at low cost greatly reduces the slash menace and at the same time leaves young growth and remaining trees uninjured as a nucleus for the second crop.

OTHER METHODS OF SLASH DISPOSAL

Because of their local use here and there in the ponderosa pine type, several other slash-disposal practices, which in reality are modifications of the three methods already described, have come to be known as distinct methods.

One of these is spot burning. By this method the larger accumulations of slash are fired separately, and thinly scattered slash is left unburned. Advantage is taken of skid roads to prevent the fire from spreading between bodies of slash, and occasionally rough fire lines are made for the same purpose. Ordinarily, no effort is made to move the slash away from reproduction or remaining trees. This method of disposal has been the common practice of operators who have desired to make a first step in the way of improvement over broadcast burning. The method is widely practiced in the region and is accepted by the State foresters of Oregon, Washington, and Montana as satisfactorily complying with the State laws for abatement of the slash menace. In Montana, where the State law requires a minimum expenditure of 15 cents per thousand board feet cut for slash disposal, the operators generally deposit the required amount with the State forester, whose organization then handles the disposal job. As 15 cents is not enough to permit piling and burning, the State forester carries out a careful type of spot burning on these private lands.

Examination of spot-burned areas reveals frequently as much as 50 percent of the ground burned over and a great deal of destruction of reproduction and seed trees. Where some degree of care was used and the burning was done at a safe season, a considerable amount of slash was left unconsumed. On the other hand, where the burning was done at a time when a more complete clean-up was secured, the result was but little better than a broadcast burn. On five areas in Oregon studied by Munger and Westveld (*23*), where the work was done at low cost, the reproduction killed was found to amount to 19, 19, 31, 47, and 77 percent, respectively. Where more money was made available for the job, as in Montana, much less damage was done. On the whole, the method cannot be practiced without destroying considerable reproduction and remaining trees and thus removing a very appreciable proportion of the cut-over land from productiveness. It cannot be recommended, therefore, as a safe measure for general use in timber-growing practice. Under restricted conditions, however, such as on areas containing but scant and scattered groups of reproduction and small trees, spot burning may be used effectively and cheaply to clean up slash in the openings. Its use in such cases should only be as an alternative to safer methods employed on the operation as a whole.

Swamper or progressive burning is a method by which swampers throw green slash on burning piles as they work. As it is comparatively easy to burn material in this way once the fires are well started, each pile takes care of slash within a considerable radius. For this reason there are less burned spots and less possibility of damage than in regular piling and burning. The difference between the two methods is that the latter is accomplished in two operations, piling

being done throughout the year and burning only in the fall or spring, whereas the swamper method is performed in one operation and is restricted entirely to the wet seasons of the year. Carried out carefully and under the proper weather conditions, the method is safe and cleans up the ground very well. Perhaps the greatest advantage of this system is the elimination of slash that would ordinarily be carried through the summer when it is most dangerous. Furthermore the method, by disposing of slash in advance of skidding, materially reduces skidding costs wherever horses are used. Where piling and burning in two operations is the regular method employed, swamper burning can advantageously be substituted during the seasons when burning is safe. The method can also be used, in the proper season, for cleaning up strips as a part of the partial-disposal measure already discussed.

Lopping and scattering and lopping without scattering are refinements of the practice of leaving slash on the ground. These measures have been tried in national-forest cuttings in the Southwest (*25*). The original object of lopping is to hasten decay and disintegration by getting the slash in close contact with the ground. In this region, however, Boyce's observations (p. 20) are that lopped slash decays less rapidly than undisturbed slash. It is doubtful whether lopping of slash has application in the Northwest, except possibly in certain cases of steep slopes where it may be desirable to protect the soil against erosion.

DISPOSAL IN LARCH-FIR STANDS

The larch-fir stands which occur within the ponderosa pine type, because of their comparatively dense mixture of trees of all sizes, present a somewhat different situation with regard to fire danger. Branches are often continuous from the ground to the tops of the larger trees. Under these conditions broadcast burning and uncontrolled spot burning are entirely out of the question. Except in parts of western Montana where larch fir forms a major forest type, cutting is very light, amounting to a mere culling of the forest. Thus very little logging debris is produced and the situation is not as bad as it would be if cutting were as heavy as it is in pine stands. Moreover, the dense cover in these lightly cut stands naturally results in greater soil moisture and lessened wind movement, thus making for a shorter fire season. Examination of old cut-over areas logged for mine timbers showed that the slash menace had been practically eliminated in 15 to 20 years. Piling and burning along strips and leaving the slash elsewhere, as suggested for ponderosa pine, is, therefore, proposed as a minimum forestry measure. As the larch and fir logged in this region occur chiefly as small bodies entirely surrounded by ponderosa pine, protection by cleared strips will be comparatively easy. What the final method of slash disposal for these mixed stands should be if heavy cutting were to produce a great mass of debris cannot be stated at the present time. Experience with the methods proposed for present conditions will help to indicate the character of a more intensive method whenever that becomes necessary in the future.

FIRE PROTECTION

THE GENERAL PROTECTION STANDARDS

As continuous production in the ponderosa pine forest is so vitally dependent upon keeping out fire, there must be the highest standard of fire protection. This means protection not only of the virgin forest, but also of young growth on cut-over land. It means, in fact, protecting reproduction at all times—before, during, and after cutting.

A desirable standard of protection would be one in which the average area burned each year would not exceed 0.3 percent of the entire forest area, or 3 acres to each 1,000 acres. The existing practice is still far from approaching this standard. Fires that threaten damage to mature timber are reasonably well controlled owing to the protection afforded by the State forest organizations and by the private timber-protective associations. In Oregon, Washington, and Idaho compulsory patrol laws are particularly effective, providing that the private owner must protect his timberland and, if he does not, empowering the State to furnish protection and to charge the cost to the owner. In Washington the law limits the charge to 5 cents an acre, in Oregon to 5 cents with certain exceptions, and in Idaho it provides for charging the actual cost per acre.

The cooperative system of protection by associations of timberland owners is well illustrated by the situation in Oregon.[11] Fire protection for all the forest area of the State, outside the national forests, is provided by a number of timber protective associations and by several State units. Each association has a warden and an executive officer who employ the protective force and attend to the details of operation. The State approves the selection of association wardens and pays half their salaries. The State also has field inspectors, whose duty it is to keep the association activities up to uniform standard, and further provides law-enforcement men to look up slashings, to inspect mills, logging operations, and other hazards, and to provide for compliance with the fire code. The State protection units, each with a warden employed by the State forester, cover areas the owners of which cannot belong to associations or who do not voluntarily protect their lands. As protection is compulsory, the cost is assessed against the owners and collected in the same manner and at the same time as taxes. In the case of the associations, the cost of protection is covered by assessment of members and by Federal money granted under the Clarke-McNary law and allotted through the State forester.

The associations located in the pine territory protect a total of about 4,000,000 acres of private timberland, the area of single associations ranging from about 200,000 to over a million acres. Table 1 shows the record of these associations for 6 years, including the bad fire years of 1929 and 1931. The areas burned in the latter years were 0.68 and 0.96 percent, respectively, of the area protected. In 1927 it was only 0.06 percent. An annual burn of 0.3 percent as an average through a period of good and bad years is regarded as a satisfactory standard of protection. The average annual burn of 0.47 percent obtained by these associations approaches such a standard.

[11] The facts in this presentation were obtained from annual reports of the State forester of Oregon and from E. H. McDaniels of the Forest Service at Portland, Oreg.

TABLE 1.—*Record of fire-protective associations in eastern Oregon*

Year	Area patrolled	Men used on patrol	Fires	Area burned			Patrol and suppression cost per acre	Proportion of area burned of total area
				Merchantable timber	Second growth	Cut-over, burned over, and brushland		
	Acres	*Number*	*Number*	*Acres*	*Acres*	*Acres*	*Cents*	*Percent*
1927	2,358,743	59	192	630	315	483	2.5	0.06
1928	3,854,524	57	355	8,160	3,540	8,589	2.8	.53
1929	3,988,578	82	393	8,750	3,805	14,643	3.5	.68
1930	4,061,621	88	395	2,876	4,669	5,667	2.9	.33
1931	4,149,763	74	433	13,869	3,272	22,814	3.5	.96
1932	4,256,497	62	306	163	644	3,483	1.5	.10

The weak point in protection practice in the region has been the failure to provide adequately for the preservation of young growth. An inducement to better protection of young growth is found in the recently enacted reforestation laws of Idaho, Oregon, and Washington, which have the effect of making the current tax burden light until the stand is harvested. The Clarke-McNary law, with its provision for matching Federal money with State and private funds for fire protection, is also an incentive for better protection of young growth and for a general raising of the standards of fire protection.

The intensity of fire protection, and to some extent the methods, vary with the condition of the forest, depending upon whether it is uncut timber, cut-over land, or timber in the process of being logged. The greatest fire danger exists during logging, with slash on the ground and multitudinous causes of fires present due to the activity of logging employees and equipment. The next serious condition of fire danger exists on cut-over land following logging. There is much less danger in virgin timber.

PROTECTION DURING LOGGING

It will bear repeating that a logging operation is one of the highest classes of fire risk. Many fires are started by logging locomotives and other engines, despite the use of spark arresters; by insufficiently controlled burning of slash immediately around camps and engine settings; by men smoking on the job; and by lunch fires left unextinguished. In this region as a whole lightning comes first as a cause of fires, and campers also rate high in the list of causes.

The first step in fire protection during logging is to take the utmost precautions to prevent fires from starting, and the second is to suppress promptly such fires as do start. The chief rules for prevention and suppression may be outlined as follows:

(1) Prevent fire escaping from logging machinery by using oil wherever possible instead of wood or coal as fuel on locomotives, skidders, and all spark-emitting equipment; by the use of effective spark arresters and devices to prevent escape of live coals from ash pans and fireboxes; by designating specific localities where flues may be sanded; by instructing engineers in the care of spark arresters, the dumping of ashes, and the sanding of flues; by screening exhausts on motor equipment. Frequent inspection of all devices here mentioned is necessary.

(2) Clean up strips and spots where fire is most likely to start. This should always include the removal of slash and the felling of snags on strips about 100 feet each side of railroads and on all sides of camps, landings, engine settings, and other used or frequented spots. Although these strips are put in primarily to protect the logging operation, they later become an important part of the network of cleared strips of the partial slash-disposal system.

(3) Prohibit smoking in the woods during the fire season. Restrict lunch fires and fires to heat chute grease to safe and especially prepared spots. Prohibit the use of camp fires and see that care is exercised in the use of fire of any sort in the logging area. Post signs to keep these regulations in the minds of employees and others and see that the regulations are strictly enforced.

(4) Organize systematically for fire protection. In the case of larger operations this means that there should be a camp fire warden whose entire time should be given to fire prevention and suppression. It should be his responsibility to organize the camps for fire control, to instruct the men in their duties on fires, to inspect all tools and fire equipment, and to see that they are kept in perfect condition. On smaller operations where the full time of a camp fire warden is not required, he may be given other duties, but his primary responsibility should be fire protection. In cases of still smaller operations, the logging foreman or some other specified individual should be made responsible for action in case of fires. Unless some one man is designated in this way there is sure to be delay in attacking fires due to the tendency to take a chance or to go on with the work in hand and let someone else attend to the fire. In the same way someone should be made responsible at each "side" or logging unit to direct fire fighting until the arrival of the foreman or the camp fire warden. In this connection it might be mentioned that the best protection a logging operation can have is a logging superintendent who is fire-minded. A telephone system connecting various parts of the logging operation is necessarily a part of good organized fire protection.

(5) Provide fire patrol to follow trains. Properly equipped speeder patrol should carry a shovel, ax, rake, and grub hoe, and also a small water tank and hand pump.

(6) Provide equipment strategically located for immediate use in fighting fires. This means that there should be located at each logging camp a box of fire-fighting tools containing shovels, axes, rakes, grub hoes, and crosscut saws sufficient to equip a fire-fighting crew adequate to handle any fire situation which may arise on the logging operation. It means also that each locomotive, skidder, tractor, truck, and other logging machine should carry sufficient fire-fighting tools to equip 2 to 15 men for immediate action on fires. A chemical fire extinguisher should be standard equipment on all trucks and tractors. Each locomotive and logging machine should be provided with 300 feet of hose. On railroad operations there should also be a tank car of adequate capacity with power pump and at least 1,000 feet of hose. Depending upon the availability of water, portable power pumps, each equipped with a thousand feet of hose, will prove invaluable on both the small and large logging operations. To be sure that all fire-fighting equipment is ready for use when needed, provision should be made for

keeping it in special places at the machines and in the camps. It should be strictly understood that tool boxes are to be opened only in case of fire. Unless this is done there is always the danger that shovels, axes, and the other tools will be scattered on the logging job and will not be available when needed.

(7) Provide for watching steam-operated machines, wherever such are used, at noon and an hour or two after quitting time, to prevent fires starting from sparks which may be emitted in the absence of the crew.

(8) In cases of extreme emergency when safety cannot be secured by observing the foregoing measures or by additional precautions, provision should be made to shut down the woods operation for the period of extreme danger.

The likelihood of fires being started by locomotives and other logging machinery cannot be overemphasized. On a large private operation in California the record for 1 year showed that 95 percent of the fires were due to these causes (*28*). Although the use of spark arresters and other devices for preventing the escape of fire is of first importance, it is obvious that until such devices become thoroughly effective for the purpose intended without impairing the operating efficiency of engines, fires will start where locomotives, loaders, and such equipment are in operation. It should be mentioned in this connection that tractors have been known to start fires and that this also should be watched for and prevented.

Although the measures for protection during logging here outlined naturally have continuous forest production as their primary objective, it is obvious that they serve equally well as a highly desirable form of insurance for logging equipment, standing timber, and other property connected with the operation.

PROTECTION OF CUT-OVER LAND

Although the completion of logging and the withdrawal of men and machinery eliminate most of the causes of fires which make an area so great a risk during the logging operation, the situation with regard to fire after cutting, even with complete disposal of slash, is always such as to require the most careful planning for the protection of the cut-over land. Where there is complete piling and burning of slash the standard of protection is somewhat similar to that in the virgin forest. The same methods apply in general, though there is need for more speedy control, for the reason that vegetation is more abundant and dries out sooner on cut-over land, and because there is more at stake. Reproduction is destroyed by a grass fire, whereas older trees are rarely killed outright by this type of a fire. Where the method of partial disposal is employed and slash has been left on much of the ground, there is obviously need for special protection measures which must be carried out as a necessary follow-up of the slash-disposal system.

The determination of effective protection measures for cut-over land, as under other forest conditions, involves first a consideration of the causes of fires on such areas. After the first year of logging, spark-emitting machinery is eliminated as the largest cause of fires, but does exist in the form of one or two trains of logs a day over the main line. In many cases the main source of fires will be from smoking and camp fires, owing to increased travel and overnight

stops by campers, berry pickers, and others on the many logging roads and trails which have opened up the area. Lightning sets fires on cut-over land as well as elsewhere in the forest, and the detection force must always be watchful for such fires following electric storms.

As the fire-starting agencies make themselves felt mainly along the routes of travel, it is logical that the protection effort should be concentrated along such routes. The measures of prevention, detection, and suppression that are indicated are the following:

(1) Restrict smoking and building of camp fires to designated camp sites and prohibit them elsewhere on cut-over land during the fire season.
(2) Continue to enforce for logging locomotives and other machinery passing through the cut-over area the same precautions specified for protection during logging.
(3) Maintain a lookout and patrol system adequate to insure prompt detection and suppression of fires while small. This will mean, among other things, speeder patrol following railroad trains through the area, and foot, mounted, or auto patrol as called for elsewhere. It will also mean the location of tool boxes and telephones at appropriate points over the area.
(4) Have the organization and equipment at logging camps, which are designed primarily for the protection of the going operation, available also for fighting fire on cut-over land.
(5) As a measure of improved protection, it would pay to convert the main artery railroad grades into roads passable for auto travel in order to make the cut-over territory quickly accessible to fire-fighting crews. It is believed that this can be done for $150 to $200 a mile under average conditions in this region.
(6) Ti carry out these various protection measures requires an overhead agency such as a camp fire warden or association fire warden who will be held responsible. In many cases this will be the camp fire warden who has charge of the protection of the going operation and contiguous green timber. In any case there should be a definite understanding and agreement between the operating and protection departments of companies as to the responsibility of each for fire suppression on definite areas.

Detection requires lookouts and patrolmen, or in many cases combined lookout patrolmen. If the cut-over acreage is large enough, or if there is a timber-protective association embracing the holdings of several owners, it will be possible to have the benefit of a stationary lookout who has a designated territory under constant observation. One stationary lookout for approximately 50,000 acres insures reasonably good detection. Patrolmen serve both for detection and quick suppression. The intensity of patrol service will vary with different conditions, but chiefly with the age of the cutting. In the case of newly logged portions of cut-over land, where the slash is still in a highly inflammable stage, the unit of area which one lookout patrolman can cover effectively is comparatively small. It should not be much larger than 5,000 acres during the first few years following cutting. As the slash danger gradually decreases from year to year, the unit to be covered by one patrolman may accordingly be enlarged. An example may be assumed in which the patrol unit begins at 5,000 acres, increases to 10,000 at the end of 5 years, and to 15,000 at the end of 10 years. It would not be safe under ordinary conditions to increase the area covered by one man beyond 15,000 acres.

PROTECTION OF VIRGIN TIMBER

The lower fire danger in virgin timber as compared with that in the forest during and after logging is due chiefly to absence of slash and less prevalent fire-starting causes. Moreover, the shade of the virgin forest conserves moisture and delays the drying out of vegetation and soil cover, and thus makes for a shorter fire season than on cut-over land. In the arid pine region, however, there is always a prolonged dry season and fire is always an imminent possibility. Lightning is an ever-recurring cause of fires, along with campers, fishermen, hunters, and berry pickers.

For the most part, fires in the virgin forest are surface fires which run over the ground and destroy the advance growth of seedlings and saplings and produce fire scars and pitch butts on the larger trees. Crown fires, however, do occur in ponderosa pine timber, despite its open character, and conflagrations of this sort have destroyed valuable standing timber. From what has already been said of the vital importance of advance reproduction as the basis of the second crop after logging, it is clear that protection against surface fires must be one of the first objectives of an effective protection system in the virgin forest. Such a system should be adequate to detect fires promptly and to put them out while they are small. Briefly, this means a protection system that will include proper lookout and patrol service, fire guards to start suppression work, fire-fighting tools and equipment, means of transportation, trails, roads, and telephone lines. The detailed measures for prevention and suppression will be the same in many respects as those already outlined for protection during logging and on cut-over land and need not be repeated here.

COST OF SLASH DISPOSAL AND PROTECTIVE MEASURES[12]

The costs of slash disposal and protection will naturally vary with the character of timber, topography, and other factors. For the system of partial disposal and intensive protection, with 20 percent of the cut-over area in strips, with piling and burning of slash at 35 to 75 cents a thousand board feet of cut and snag felling at 10 cents a thousand, the costs per thousand board feet cut will range somewhat as follows:[13]

Where all the slash on strips is piled and burned

Piling and burning all slash on strips and around camps, skidders, etc	$0.07 to $0.15
Snag felling on strips and other restricted spots	.01 to .03
Special patrol during and after logging for 15 years at approximately the following cost per acre per year: $0.08 for the first 5 years, $0.04 for second 5 years, and $0.026 for the third 5 years	.04 to .05
Stationary lookout to supplement lookout patrolmen	.01 to .01
General protection items, including fire warden, tools and equipment, telephone system, etc	.05 to .06
Total	.18 to .30

[12] Because of the unsettled wage scales for the last 2 or 3 years these costs are based on the average wages that prevailed between 1926 and 1930.

[13] These costs correspond very closely to those found by Munger and Westveld (23) in their study covering part of the northwestern pine region.

Where part of slash on strips is spot burned and part piled and burned

Disposal of slash on strips	$0.03 to $0.05
Snag felling item	.01 to .03
Special patrol item	.04 to .05
Stationary look-out item	.01 to .01
General protection items	.05 to .06
Total	.14 to .20

In the first case, the initial operations of slash disposal and snag felling cost from $1.20 to $2.70 an acre, and the intensive protection $0.10 to $0.12 an acre a year for 15 years. The average cut per acre assumed in these figures is 15,000 board feet.

In the second case, where the removal of the slash on strips is accomplished by careful spot burning of the larger accumulations and piling only the scattered debris, the initial work will be reduced to a total of only $0.60 to $1.20 per acre with the intensive protection the same as in the preceding case.

Among the factors that cause variation in cost of disposal is the area in strips. The 20 percent here used is a relatively large proportion of the area to be devoted to strips. The Fruit Growers' Supply Co. is getting effective fire control with about 10 percent of its cut-over land in strips. By reducing the strip area in the above figures to 10 percent, the total costs would be decreased about 25 percent. The wide spread in the basic cost of piling slash is still more of a factor in causing variation of total costs. Wherever the ground is steep, the timber small, and much fir and larch is found in mixture with the pine, slash piling costs will approach the upper figure given. In purer, heavier stands of pine on gentle slopes, the piling costs will be close to the lower figure. The average total cost for slash disposal and subsequent protection for the region as a whole should not greatly exceed the minimum cost shown in the above tabulations.

In considering these cost figures, it is important to bear in mind that they include not only slash disposal proper, but also protection during logging and protection of cut-over land for 15 years following logging. Moreover, they include the costs of measures for protecting camps and logging equipment that an operator would incur regardless of whether he disposed of slash or protected his cut-over land. In fact, if this customary cost of protecting logging property against loss by fire could be separated from the figures listed, it would be found that the sum an owner would need to spend for slash and protection measures on cut-over land would amount to about 10 cents a thousand board feet.

Spot burning on the cut-over area as a whole is not recommended as a method compatible with timber growing. It may be acceptable, however, when practiced carefully in combination with piling and burning in strip disposal. The cost varies greatly with topography, density of timber, and the care exercised to hold damage to a reasonable minimum. In open stands of ponderosa pine on gentle slopes, spot burning may be done for 2 or 3 cents a thousand board feet. In dense stands, on steep ground, with larch and fir mixed with the pine, the cost may run to 15 or 20 cents a thousand. In Montana, the 15 cents a thousand required by State law as a mini-

mum expenditure for slash disposal is not enough to keep spot-burning damage entirely within bounds.

The costs of fire protection in virgin pine timber are fairly well established, through long experience of both the Forest Service, the States, and the private timber-protective associations. The total costs of protection, including prevention, detection, and suppression range from about $0.015 to $0.035 an acre a year. This is about the range of association costs where high values are protected under conditions of relatively high risk. On a national forest in western Montana, containing a large acreage of ponderosa pine type, the average annual protection cost for the 5-year period ended in 1930 was $0.025 per acre, in which the presuppression cost amounted to $0.018 and the suppression cost to $0.007. Although private timberland, being at lower elevations, suffers less from lightning fires than national-forest timber, it is located in more populated country where it is subjected to more and a greater variety of causes of fires. For this reason the cost of effective protection will probably exceed that on national-forest areas. An expenditure of about 2 to 4 cents an acre a year, however, will give the protection needed in the virgin forest to control fire and prevent the destruction of advance reproduction which is found on the ground before logging and is so necessary as a basis for the second crop.

METHODS OF CUTTING

NO RESTRICTIONS IF YOUNG GROWTH IS PRESENT

Where the virgin forest before logging contains the minimum quantity and distribution of reproduction or of small trees prescribed earlier in this bulletin, no special cutting restrictions are necessary for minimum productiveness. Given careful execution of slash disposal and fire protection as here recommended, the nucleus of young growth already on the ground will bring about the accepted condition of cut-over land. And, as has already been shown, much of the virgin timber of the region does contain a sufficient amount of advance young growth for this purpose.

SOME SEED TREES NEEDED IN ABSENCE OF YOUNG GROWTH

Where advance reproduction is lacking as it is on nearly a fifth of the virgin timberland in the region as a whole, the leaving of some seed trees will naturally be a requirement. It is important to realize, as has already been shown, that seedlings will not come in after the cutting of timber anywhere near as readily and abundantly as advance reproduction, which starts in the presence of a full seed supply and under the shelter of the virgin forest. Not only is less seed available, but the ravages of rodents and cone-boring insects, and the effect of climatic conditions on seedling survival take a heavier toll of seeds and seedlings in the open than under the forest shelter. Thus what reproduction is obtained after logging will in most cases be the result of a slow accumulation of surviving seedlings from the better seed crops which come periodically.

How often seed trees may be expected to bear abundantly is indicated by annual observations of cone crops in three widely separated parts of the region. Twenty-one years of record in western Montana

reveal 5 good, 6 fair, and 10 poor seed crops. The intervals between good crops ranged from 2 to 6 years. Seventeen years of observations in eastern Oregon show that abundant seed was borne in 1912, 1917, and 1923, with a record of fair to abundant for 1928. This is a consistent interval of 5 and 6 years. The remaining years were fair, poor, and failures, with 4 years definitely in the latter category. A record of 8 years in central Idaho gives 1 good, 2 fair, and 5 poor seed years.

Capacity of individual trees to produce seed in quantity is governed chiefly by size and health of crown and density of foliage. This follows quite closely and in direct ratio to size of tree in diameter. For practical purposes, therefore, size of tree is the most workable index of seed-producing ability. From cone-crop studies involving over 300 trees of all sizes down to 8 inches in diameter, it was learned that ponderosa pine trees do not become effective as seed bearers until they reach a size of 16 to 18 inches.

The number of seed trees required is governed by the quantity of seed needed to establish a given crop of seedlings. Fifteen years of annual observations of permanent sample plots indicate a drain of as much as 80 percent, chargeable to rodents and insects, and following that, a mortality of more than 90 percent of all seedlings that germinate. It is evident from this that a tremendous amount of seed is necessary to secure a very small amount of established reproduction. The indications, however, are that two good 18-inch trees could be expected to produce a minimum crop of about 200 seedlings per acre, in a reasonable period.

It is not here proposed that two 18-inch trees per acre be set as a seed-tree requirement, but merely to indicate what would be necessary if the minimum of hand-picked seed trees were to be selected. The proposal of this bulletin is that all the small trees below a certain diameter limit be left to provide the necessary seed supply. As has already been indicated, the smaller trees do not bear seed as abundantly as trees 18 inches in diameter or larger, but if there are enough of them, their combined cone production will meet the requirements.

REQUISITE SMALL SEED TREES OBTAINABLE IN STAND IF NEEDED

The indications of the present data are that in the northwestern pine territory 10 or more trees per acre between 8 and 16 inches in diameter are sufficient for minimum seeding purposes. The question now is whether there are enough small trees in the stand to meet this requirement. To determine this, timber-cruise tallies aggregating 864 acres and representing 13 typical localities throughout the region were examined. The results are presented in table 2 by numbers of trees per acre found in the different diameter classes.

From table 2 it is apparent that there are somewhat more than the required 10 ponderosa pine trees per acre between 8 and 16 inches in diameter in the average stands of the region. Where the variation from the average contains fewer than the required pines, the deficiency, as shown graphically in figure 6, is amply made up in all but two instances by the generous admixture of seed trees of other species.

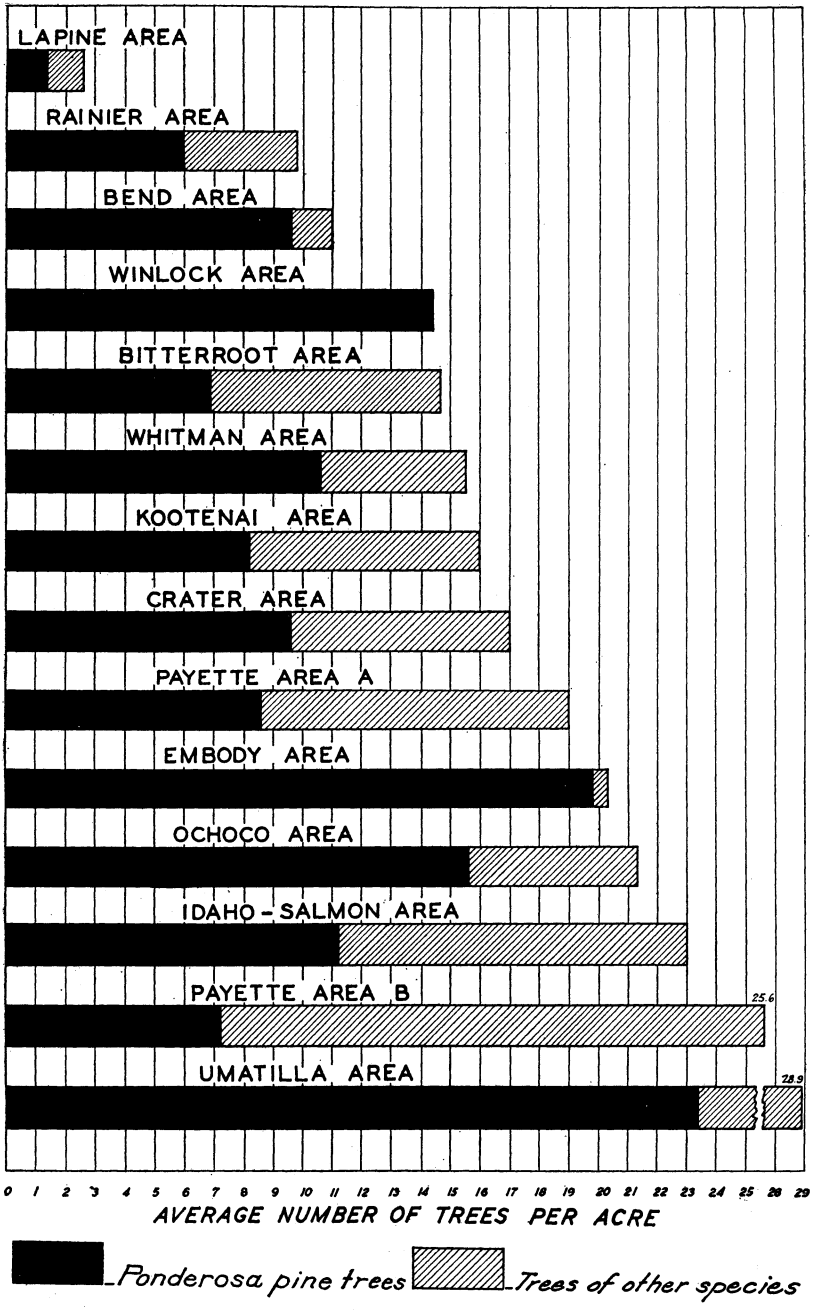

FIGURE 6.—Number of trees from 8 to 16 inches in diameter, inclusive, found in the virgin forest in 14 localities within the ponderosa pine region. The data indicate that there should be at least 10 such trees per acre to assure the minimum seed supply. Including larch, Douglas fir, and other species with the pine, it is obvious that a sufficient source of seed exists on all but two of these areas. Except for the Bend area, these are the same areas listed in table 2. That designated Lapine is Deschutes B, Winlock is Umatilla B, Embody is Deschutes A, and Umatilla is Umatilla A.

TABLE 2.—*Ponderosa pine trees per acre of different sizes found in virgin stands in various areas within the region* [1]

Diameter breast high (inches)	Whitman (258)	Umatilla A (44)	Umatilla B (20)	Ochoco (20)	Deschutes A (30)	Deschutes B (40)	Crater (159)	Rainier (4)	Payette A (32)	Payette B (44)	Idaho-Salmon (69)	Bitterroot (100)	Kootenai (44)	Average all areas (864)
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
8	2.29	5.02	4.50	3.40	4.73	0.32	2.09	----------	2.50	1.09	2.23	0.62	0.86	2.13
10	1.90	5.11	2.55	3.10	4.33	.22	1.94	----------	1.75	2.54	3.16	.85	1.13	2.16
12	2.01	5.27	2.85	2.90	3.27	.25	1.79	1.50	1.27	.80	2.28	1.50	2.09	2.01
14	2.23	4.52	2.80	3.20	3.83	.35	1.84	2.00	1.22	1.58	1.61	2.11	1.64	2.11
16	2.21	3.43	1.70	3.05	3.67	.25	1.99	2.50	1.90	1.14	1.96	1.78	2.49	2.08
18	2.54	3.34	1.35	3.15	3.30	.42	2.09	2.00	1.34	1.24	1.79	1.98	2.53	2.16
20	2.65	2.52	1.40	3.45	2.83	.65	2.35	1.25	1.65	1.21	(2)	2.33	2.14	2.28
22	2.50	2.86	1.50	3.50	2.80	1.00	1.96	2.00	1.50	1.32	(2)	2.45	1.82	2.19
24	2.45	2.75	1.65	3.70	2.23	1.10	2.27	1.75	1.68	1.73	(2)	2.69	1.53	2.28
26	2.26	2.68	1.25	2.25	2.20	1.15	1.99	.50	1.50	1.63	(2)	2.11	1.07	1.99
28	1.99	2.07	.95	2.00	1.70	1.22	2.46	1.00	1.40	1.43	(2)	1.75	.87	1.85

[1] These stand figures do not include trees larger than 28 inches or trees of other species associated with ponderosa pine. Data for the first 3, the fifth, sixth, and seventh areas were taken from studies by Munger (*22*). Figures in parentheses in headings represent basis in number of acres tallied.

[2] Stand above 18 inches d. b. h. not included.

The most practicable method of effecting the reservation of the small trees is to cut strictly to a diameter limit. This means that if 16 inches is the diameter limit, no trees 16 inches or less in size should be logged. It may be well to point out that although some of the smaller trees may bear few or no cones at the time of cutting, liberation due to opening up of the stand causes them to undergo a greatly increased diameter growth and vigorous crown development, which in turn effect an equally early and marked increase in their seed-producing capacity.

Although the board-foot volume contained in small seed trees has little significance in determining the cost of leaving them, as will appear later in this discussion, it is of interest to know what footage is caught by cutting to a 16-inch diameter limit. Studies widely distributed over the region indicate that the volume in ponderosa pine between 12 and 16 inches d. b. h. varied from approximately 450 to 1,000 board feet per acre. The volume in trees of other species ranged from about 200 board feet in most localities to as much as 700 or 800 board feet an acre in Montana and Idaho, where pine-larch-fir mixtures are more common.

EFFECTIVENESS OF SEED TREES

The question has been raised of the effectiveness of seed trees as a method of regenerating blank ground in the pine region. This is based on observations of the slowness and scantiness with which reproduction has become established, particularly on areas logged in the last 15 or 20 years. The cause is quite evidently the unusual period of drought which the region has experienced during the last 2 decades. This is reflected not only in the great difficulties reproduction has had in getting established, but also in a general slowing-up of annual ring growth in trees. A climatic fluctuation of this sort is to be expected, but should not be taken as the prevailing condition. That seed trees have formerly been effective, and that they have even been reasonably so in the present dry period is evident from table 3. This shows for 10 cut-over areas the seed trees left per acre and the number of seedlings established by them in the first decade after logging.

TABLE 3.—*Effectiveness of ponderosa pine seed trees in establishing reproduction after cutting*

Cut-over area	Seedlings per acre established 10 years after cutting	Seed trees 12 inches and over left per acre	Decade represented	Cut-over area	Seedlings per acre established 10 years after cutting	Seed trees 12 inches and over left per acre	Decade represented
	Number	*Number*			*Number*	*Number*	
Keno	72	7	1906–15	Pokegema A	600	8	1895–1904
John Day	256	2	1892–1901	McEwen	624	4	1899–1908
Blanchard	352	4	1909–18	Bates	684	12	1914–23
Pokegema B	416	3	1898–1907	Odessa	1,720	8	1891–1900
Ochoco	528	6	1902–11	Sumpter	3,080	6	1898–1907

Nine of the ten areas studied show more than enough new reproduction established at the end of 10 years to meet the requirements of minimum productivity. Except for the Bates area, all the cut-

ting here represented was on private land where no conscious effort was made to leave seed trees, much less to select them in any way. It is only fair to state, however, that the trees left on several of these areas contained sizes up to 22 inches and in some cases larger, a situation typical of the nineties when most of this logging was done. One the other hand, the remaining trees on the Keno, John Day, and Blanchard areas were relatively small. The four trees per acre on the last mentioned tract ranged from 12 to 17 inches in diameter, but in addition there were six trees between 8 and 11 inches. Incidentally, this is about the number and range in sizes of trees that will be left by a 16-inch diameter limit. Another fact shown by the table is that two of the successfully reproduced areas, those of Bates and Blanchard, were logged during the dry period of years.

Planting is sometimes suggested as a method of restocking blank ground after logging. Actually, it can only be considered as an alternative to seed trees in the case of intensive forestry. Planting will ordinarily be too costly where the aim is simply to leave cut-over land reasonably productive.

PROFITABLENESS OF LEAVING SMALL TREES IN ANY CASE

Regardless of the amount of young growth on the ground, whether seedlings, saplings, or poles, it will always be desirable to leave the small trees which are on the border line of merchantability. It will not only be desirable; it will in most cases actually be profitable for the operator to leave standing the smaller trees he now logs. The fundamental reason for this is that the small trees yield less profitable lumber grades and are logged and milled at high cost.

Unfortunately, the size below which it is unprofitable to log timber cannot be stated simply as a fixed diameter limit for all conditions throughout the region. The diameter limit of most profitable cutting, which has been called the economic diameter limit, will vary with the extent of the timber holdings, the accessibility of the timber, the distribution of trees by diameter classes, logging and milling costs, values of lumber grades, and the character of logging and manufacturing facilities. In view of these considerations, it is necessary to determine the size concerned separately for each logging operation.

An actual comparison of lumber values and production costs for trees of different sizes, such as is given in figure 7, shows that the logging and milling costs per thousand feet are highest for the small trees and rapidly become less as the trees increase in size. It shows that the values, on the other hand, are low for the small trees and gradually increase as the trees become larger. In the case illustrated, the costs and values balance each other when the trees become about 19 inches in diameter. Below that size, the costs of production are greater than the lumber values contained in the trees, the excess of cost over value being $1.70 a thousand feet in 18-inch trees, $4 in 16-inch trees, and as much as $15 in 10-inch trees.

Although the costs and values will vary somewhat with wages and condition of the market, the general relationship will remain much the same as that shown in the graph. Under some conditions the size at which the values and costs will balance will be smaller than

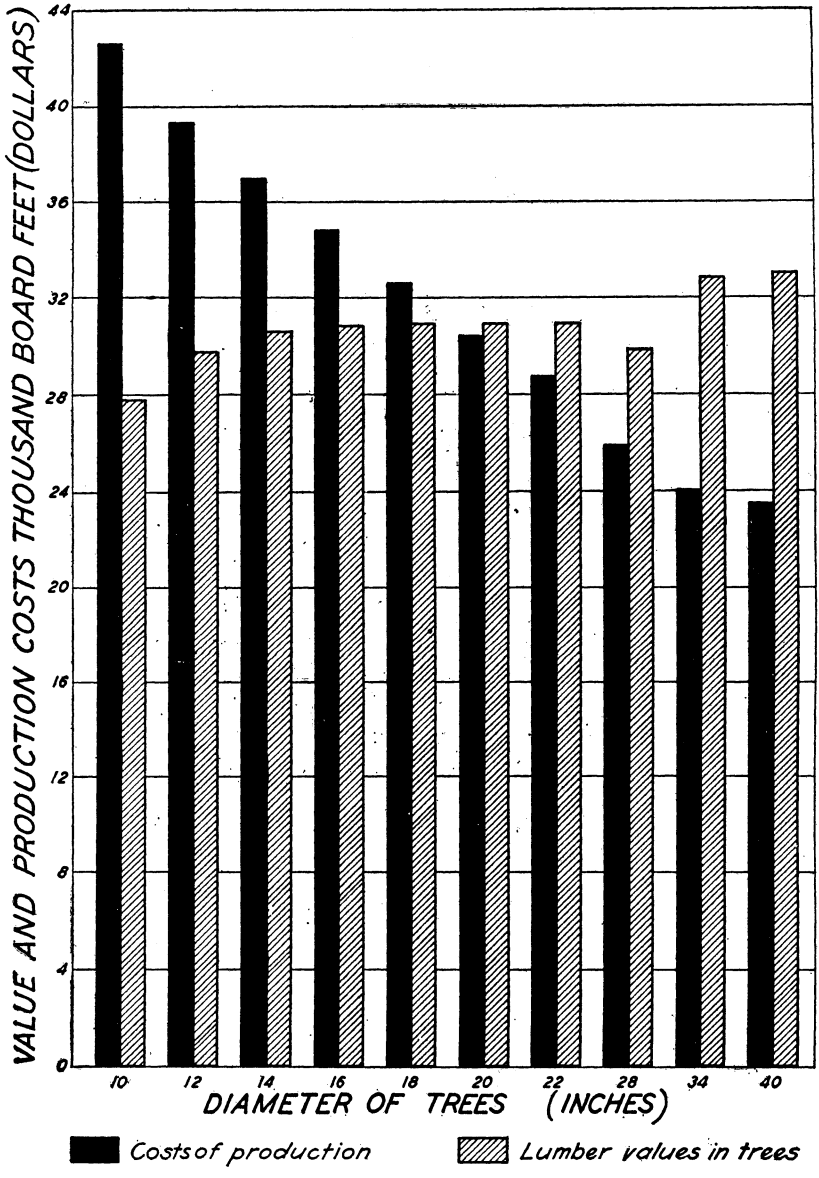

FIGURE 7.—Comparison of lumber values of sound ponderosa pine trees of different sizes with costs of production per thousand board feet, log scale. Based on time studies of felling, bucking, skidding, loading, and milling at several operations in western Montana, and using average wages and lumber values by grades for the 3 years 1925–27. The studies involved time records in some cases on as much as 600 M feet of logs in the woods and 900 M feet of logs at the mill and were based on observations made at different times by M. Bradner, S. V. Fullaway, Jr., Philip Neff, F. J. Klobucher, and J. W. Girard, all now or formerly of the United States Forest Service, Missoula, Mont. Prices used in determining the values were those of the Western Pine Manufacturers Association for the period covered.

shown, and under other conditions it might even be slightly larger. Type of logging, skidding distance, and all such factors were averaged for a number of representative operations in obtaining these figures.

The reason for the difference between the lumber values of small and large trees is readily apparent from a statement of percentage of lumber grades obtained. Table 4 gives such information for trees of different sizes. This shows that the Select grades sawed from a 16-inch tree amount to less than 12 percent of its total volume, and that Selects do not reach 20 percent of the volume of a tree until it attains a diameter of 20 inches. Shop lumber is practically absent in the smaller trees and reaches barely 5 percent of the volume of those 20 inches in diameter. The large remainder of the contents of small trees goes into common lumber. In this connection, the rather desirable No. 2 Common is found to comprise 53 percent of the volume of 12-inch trees and only 34 percent of that of 20-inch trees. It will be readily appreciated, however, that the smaller percentage of this grade in the 20-inch tree represents over three times as much lumber as the larger percentage in the 12-inch tree. This difference in favor of the middle-sized trees is only slightly reduced by the higher overrun of the small classes. Although overrun is something like 35 percent in the 12-inch trees, it still reaches as much as 30 and 20 percent, respectively, in the 20-inch and 26-inch classes. These facts would indicate that there is little justification for the belief sometimes expressed by operators that the smallest trees are the chief source of No. 2 Common.

TABLE 4.—*Lumber grades in sound ponderosa pine trees of different size*[1]

Diameter breast high (inches)	Select			Shop				Common					Total
	B and better	C	D	No. 1	No. 2	No. 3	4/4 Common	No. 1	No. 2	No. 3	No. 4	No. 5	
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
10	0.50	4.10	10.00	0	0	0	0	4.00	58.60	19.40	3.40	0	100
12	.70	4.70	12.00	0	0	0	0	2.90	52.90	22.90	3.50	.40	100
14	1.00	4.30	9.90	.60	.60	0	1.30	2.30	51.80	21.60	5.50	1.10	100
16	.80	3.30	7.50	.50	0	.30	0	1.60	42.60	36.90	5.20	1.30	100
18	2.80	4.20	11.70	.30	.40	.60	.60	.50	35.70	32.40	8.80	2.00	100
20	4.80	5.88	10.90	.20	.75	1.95	1.30	.92	34.10	32.60	5.70	.90	100
22	4.23	6.20	12.23	.40	1.60	1.90	2.20	.66	26.28	36.30	6.90	1.10	100
24	6.48	5.08	12.96	2.04	4.20	2.60	2.40	.60	29.54	28.60	4.90	.60	100
26	8.30	5.40	10.50	1.40	6.20	5.10	2.10	.10	20.80	29.20	9.20	1.70	100
28	9.68	5.89	13.31	3.72	6.60	4.43	2.70	.18	18.45	25.65	8.63	.76	100
34	5.73	4.07	12.11	6.17	11.30	6.86	3.10	.18	14.24	25.31	9.43	1.50	100
40	7.80	6.60	13.10	8.90	10.50	8.00	4.50	.10	8.10	20.60	10.20	1.60	100

[1] From logging and milling studies conducted in 1928 by the Office of Forest Products, U. S. Forest Service, Missoula, Mont.

A brief consideration of costs of the principal logging and milling steps readily explains the greater production costs of handling small trees as compared with large ones. In the exhaustive time studies conducted by the Forest Service in ponderosa pine operations in Montana and Idaho, it was found that the cost of felling and bucking a thousand board feet, log scale, from two-log trees 10 inches in

[14] From basic data collected by the Office of Forest Products, U. S. Forest Service, Missoula, Mont.

diameter was $2.21, as compared with $1.18 for cutting the same footage from five-log trees 20 inches in diameter.[14] Horse skidding required an outlay of $7.40 a thousand feet for 10-inch trees and only $2.88 a thousand feet for 20-inch trees. The cost in the case of chuting was $3.16 for a thousand feet of logs from 10-inch trees as against $1.77 for an equal amount of logs from 20-inch trees. Similarly, it cost $1.24 to load a thousand feet of logs from 10-inch trees and only 64 cents to load the same volume of logs from 20-inch trees. In the sawmill, it was found that the pond-to-green-chain cost amounted to $5.92 for 10-inch trees as against $2.99 for trees 20 inches in diameter. The total logging and manufacturing costs were 41 percent greater for the smaller as compared with large-sized trees. It should be mentioned that the figures were based on the wage scales which prevailed in the region in 1927. Although they would vary somewhat with different wage rates the ratios would obviously remain much the same.

The findings of the local studies with regard to the increased costs of handling small as compared with large trees are substantiated by similar results from the investigations of others in various parts of the United States (*4*, *8*, *9*, *10*, *15*, *39*).

The bare fact that the costs of certain logging and milling operations are considerably greater for small trees than they are for trees of larger sizes does not tell the whole story of what sizes are profitable or unprofitable to log. It is necessary to consider these factors as they relate to the stand as a whole. Fortunately, detailed studies of the effect of tree sizes on lumber values and production costs made by the Forest Service during 1928, in central Oregon and western Montana, afford the sort of data necessary for ascertaining in this way the cost of leaving the small trees in these particular localities.

The Oregon study (*16*) was conducted near Bend in practically pure ponderosa pine averaging 17,728 board feet per acre. The ground was mostly level and machine skidding was done by means of the Lidgerwood sky-line method. Table 5 shows the effect of different cutting limits on returns per acre under these conditions and reveals that the greatest return came when logging was done to and including the 16-inch trees.

In the case of the Montana investigation[15] the logging was done in the Bitterroot section and the milling at one of the larger Missoula plants. The average stand per acre contained 18,041 board feet of ponderosa pine and 1,760 board feet of other species. Skidding was done with crawler tractors on ground which varied from flat to steep slopes. The greatest return here was shown to be made in logging to and including the 14-inch trees. This diameter limit is lower than it should be, however, because no allowances were made for slash disposal, fire protection, interest, and cash discounts, as was done in calculating the total production costs for the Oregon study. If these items, which aggregated approximately $2.50 a thousand, had been included, the most profitable cutting limit here would very likely have been 15 inches.

[15] Conducted by members of the Office of Forest Products of the Forest Service at Missoula, Mont.

TABLE 5.—*Effect of different cutting limits on returns to determine cost of leaving small trees in central-Oregon timber* [1]

Diameter limit (inches)	Amount cut per acre [2]	Trees left per acre (12 inches d.b.h. and up)	Value of lumber per thousand feet [3]	Production cost per thousand feet [4]	Total returns [5]	
					Per thousand feet	Per acre
	Board feet	*Number*	*Dollars*	*Dollars*	*Dollars*	*Dollars*
9	17,728	0	26.35	19.99	6.36	127.95
10	17,716	0	26.35	19.98	6.37	128.05
11	17,679	0	26.36	19.97	6.39	128.15
12	17,613	1.22	26.37	19.95	6.42	128.20
13	17,509	2.63	26.39	19.92	6.47	128.29
14	17,355	4.12	26.41	19.87	6.54	128.39
15	17,214	5.27	26.44	19.83	6.61	128.54
16	17,009	6.49	26.47	19.82	6.65	127.62
17	16,614	8.25	26.54	19.80	6.74	126.03
18	16,333	9.43	26.60	19.80	6.80	124.77
19	15,693	11.49	26.71	19.79	6.92	121.60
20	15,324	12.56	26.78	19.81	6.97	119.33
21	14,845	13.71	26.90	19.83	7.07	116.94
22	14,022	15.39	27.00	19.92	7.08	110.16
23	13,401	16.54	27.14	19.99	7.15	106.00
24	12,611	17.76	27.21	20.13	7.08	98.32
25	11,490	19.20	27.43	20.36	7.07	89.16
26	10,596	20.23	27.56	20.60	6.96	80.74
27	9,404	21.45	27.87	21.01	6.86	70.35

[1] Based on studies conducted in 1928 near Bend, Oreg., by the Forest Service Office of Forest Products of Portland, Oreg., and its cooperators.

[2] Volume of cut is given in log scale.

[3] Values, costs, and returns per thousand board feet are based on lumber tally. Prices used to determine lumber values are those of the Western Pine Manufacturers' Association for the east Oregon district for 1928.

[4] Logging costs cover log making, skidding, loading, railroading, and unloading, and include also charges for improvements, depreciation, administration, railroad construction and maintenance, taxes, slash disposal, fire protection, and interest at 6 percent. Manufacturing costs cover all steps from pond to car and include charges for depreciation, general expense, taxes, interest, and cash discounts.

[5] Total returns represent the amounts available for stumpage and profit and interest on stumpage.

COST OF CUTTING MEASURES

In the greater part of the timber stands of the region, young growth is ample to assure continued productivity and no cutting measures are required. Even in the rarer cases of understocked or blank ground, a minimum seed supply can be provided at small cost. Where small trees 16 inches and less in diameter are left, the cost will depend on the diameter limit which begins to show a positive conversion value. This diameter limit varies with and must be ascertained separately for different timber holdings. If it is above the 16-inch cutting limit, there naturally will be no cost in providing a seed supply. Where it is below, the cost will be the difference between the returns per acre of logging to 16 inches and of logging to the profitable diameter limit of smaller sizes.

This is well illustrated by the cost computations for the two operations given in the preceding section, in both of which cases the cutting limit at which the greatest return is made happens to be less than 16 inches. In the case of the timber tract at Bend, Oreg., only the trees 15 inches and less in diameter would be left in logging to the economic diameter limit, and in the case of the Bitterroot timber only the trees 13 inches and less would be left. In each case a little less profit would be made by logging in such a way as to leave the trees 16 inches and less to meet seeding requirements. The actual cost, as shown in table 6, would be 5 cents a thousand for the Bend tract, and 8 cents a thousand for the Bitterroot tract.

From the two examples here given, it is apparent that the cost of leaving a seed source will vary with different conditions, but will not be great in any case. When spread over the entire acreage of an operation, it will average but a cent or two per thousand feet of the total cut.

TABLE 6.—*Number, volume, and cost of seed trees left in cutting to different diameter limits, on 2 areas in the northwestern ponderosa pine region*

Diameter limit (inches)	Seed trees left per acre (12 inches diameter breast high and up) near Bend, Oreg.[1]			Seed trees left per acre (12 inches diameter breast high and up) in Bitterroot Valley, Mont.			
	Trees	Volume [2]	Cost per thousand feet cut	Ponderosa pine	Other trees	Volume [2]	Cost per thousand feet cut [3]
	Number	*Bd. ft.*	*Dollars*	*Number*	*Number*	*Bd. ft.*	*Dollars*
13	2.63	170	0	1.65	1.69	208	0
14	4.12	324	0	2.70	2.48	387	.03
15	5.27	465	0	3.67	3.16	581	.03
16	6.49	670	.05	4.56	3.74	785	.08
17	8.25	1,065	.15	5.50	4.22	1,039	.18
18	9.43	1,346	.23	6.49	4.60	1,347	.25

[1] Practically pure ponderosa pine near Bend; only 1 tree per acre of other species in this stand.
[2] Volume given for ponderosa pines only and for trees 12 inches and up.
[3] It costs nothing extra to leave the mixed species in this stand.

The above discussion has dealt solely with the stumpage investment in ponderosa pine trees. In mixed stands containing less than the required number of seed trees of ponderosa pine, the deficiency will readily be made up by western larch, Douglas fir, or white fir. The study by Bradner and Fullaway (*7*) in western Montana already referred to shows that these associated species cannot be logged profitably at as low a diameter limit as ponderosa pine. There will ordinarily be no difficulty, therefore, obtaining sufficient supplementary seed trees in pine-larch-fir mixtures, and certainly none in straight larch-fir stands.

METHODS OF LOGGING

Logging may seriously affect the degree or productivity of cut-over land by destroying reproduction and small trees. The damage varies chiefly with the method employed, but also with the character of ground and timber stand and the abundance or scarcity of reproduction. Thus a given type of logging may cause little damage in one locality, but a prohibitive amount under a different set of conditions. The subject can best be discussed according to the different logging methods employed in the region.

TRACTOR LOGGING

Tractor logging, which started about the time of the World War, is the most generally used method, and appears to be rapidly replacing all other types of logging throughout the pine territory. With its lower investment in equipment and railroads, and its greater mobility, it has practically superseded steam methods where such were employed. It has in many cases penetrated into horse-logging country, replacing animals in some instances, and being used with animals in others.

Various forms of tractor logging are in use. The most common of these are direct skidding in log and tree lengths, skidding with pans, hauling with truss-wheel bummers, hauling with slip tongue and hydraulic high wheels, and hauling with fair-lead arches mounted on caterpillar treads. Each system is adapted to one or several types of country and the damage varies with the stand, reproduction, and ground conditions, and with the amount of care exercised.

DIRECT SKIDDING WITH TRACTORS

Although direct skidding and skidding with pans have been used to some extent in the region, no local studies have been made to ascertain the amount of logging damage caused. General observation, however, indicates that the damage is not great where reasonable care is used, and this is borne out by studies of tractor-skidding operations elsewhere (fig. 8).

One of these studies was conducted in mixed pine and fir stands in northeastern California close to similar timber in southern Oregon (*6*). Type Sixty tractors were used. Each tractor carried three chokers and skidded from 1 to 3 logs from the stump to the loading jammer at the railroad. The scarred ground in main skid trails amounted to 16 percent of the total cut-over ground and the area of reproduction destroyed was 27 percent. Only 5 percent of the trees 4 to 11 inches and 1 percent of the trees 12 to 17 inches in diameter were destroyed in skidding, with no destruction in trees of other sizes.

A tractor-skidding study made in Arizona pine timber (*32*) more nearly represents the pure pine stands and open ground conditions of eastern Oregon. The logs in this operation were skidded in double and single lengths with ordinarily two logs to the trip. The severely dragged ground in main trails covered 14 percent of the cut-over area and 30 percent of the reproduction was destroyed. There was no destruction of trees over 4 inches in diameter.

The damage caused by skidding with pans [16] is about the same as direct skidding. Preliminary observations made by I. V. Anderson on an operation in western Montana showed a loss of 9 percent in trees 4 to 11 inches and less than 1 percent in trees 12 to 17 inches in diameter.

Tractor skidding or hauling with truss-wheel bummers [17] has not been studied and there are, therefore, no figures available on the logging damage. The method, however, is so similar to tractor skidding insofar as trailing and maneuvering of equipment is concerned, that the damage is believed to be but little different. The addition of the bummers means a little more ground covered and consequently a slight increase in damage to reproduction.

As the use of tractors in direct skidding and their use with pans and bummers can easily be so controlled as to keep the destruction of young growth to well below one-third of the cut-over ground, these methods are compatible with minimum forestry practice.

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[16] A skidding pan is a flat, tobogganlike sheet of steel supporting forward ends of logs and constructed with front end upturned to prevent logs from gouging into ground.

[17] A truss-wheel bummer is a skidding device consisting of a crawler type of wheels supporting a low bunk upon which forward ends of logs are loaded.

TRACTORS AND HIGH WHEELS

With the rapid evolution of tractor-logging equipment in the pine region, no particular method seems to be long in vogue. This is as true of the use of high wheels in combination with tractors, until recently rather common in central Oregon, as of other methods.

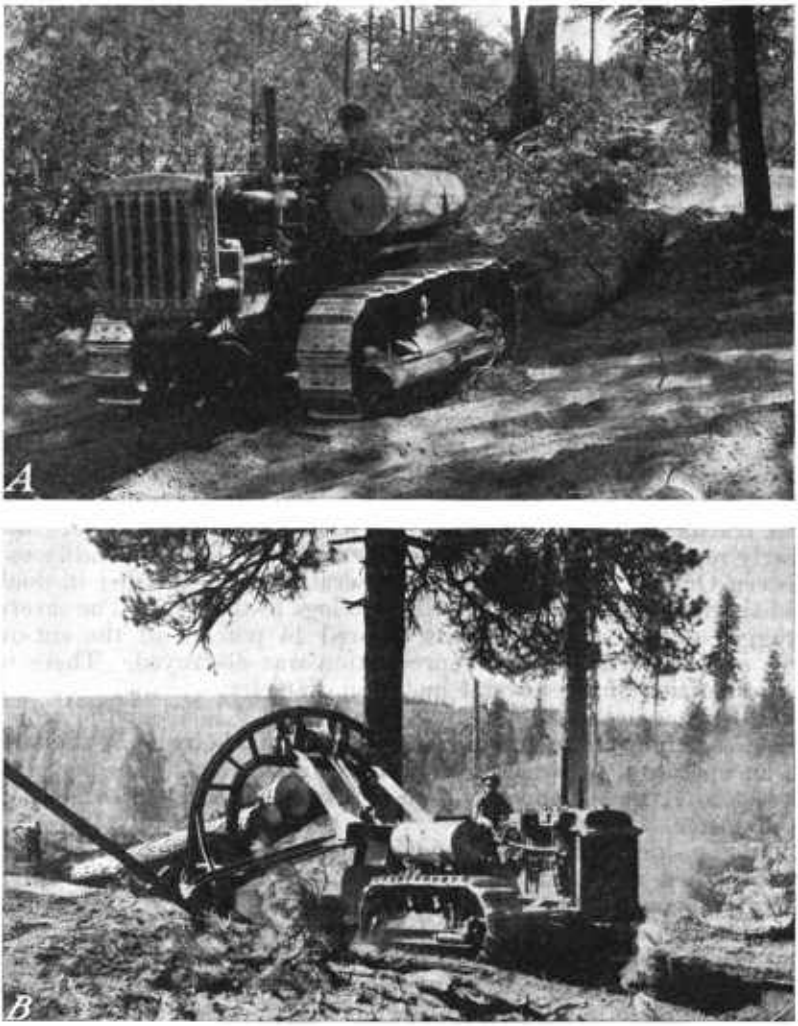

FIGURE 8.—Tractor logging using regular skid trails may be conducted so as to leave cut-over land in a productive condition. *A*, Direct skidding with tractor; *B*, skidding with tractor and fair-lead arch. (Photos courtesy of Caterpillar Tractor Co.)

Hauling with high wheels is still used to some extent, however, and careful studies of logging damage caused by the method were made in the Bend region by the Forest Service (*26*).

In one operation where the wheels were backed over the bunched logs and loaded directly in this way, 25 percent of the area was covered with wheel roads and 58 percent of the reproduction by

count, was destroyed. Thirteen percent of the trees 4 to 11 inches in diameter were damaged. Trees 12 inches and larger were uninjured. The stocking with seedlings and saplings before logging was 61 percent of the ground area; after logging it was only 39 percent. This is excessive damage, due largely to wide turning of the tractors and wheels necessary to back over the loads. Bunching of the logs in this case was done by horses. Where bunching was done with tractors even more reproduction and sapling growth were destroyed, because of the greatly increased manuevering of the tractors.

On another high-wheel operation the tractor was equipped with a skidding drum and line which could reach out for logs to a distance of 65 feet. Here wheel roads were 125 feet apart and all wheeling covered only 14 percent of the ground. In this case the stocking with young growth before logging was 98 percent of the ground area and after logging it was 90 percent. This is an example of the relatively small amount to which damage can be held in tractor wheeling if carried out with reasonable care.

As shown by the first operation here described, tractor logging with high wheels can do a disastrous amount of damage. The use of a skidding drum, however, to prevent excessive turning and backing of tractors and wheels, the planning beforehand of wheel roads and turning points, and the confining of tractor drivers to fewer routes are readily practicable means of reducing the damage. With these precautions tractor wheeling can easily be made to meet forestry requirements.

TRACTORS AND FAIR-LEAD ARCHES

The most recent development in tractor logging, and one that is rapidly coming into general use, is that of the fair-lead arch with caterpillar tread. As the distance between the treads of this equipment is about 10 feet, it covers a great deal of ground in trailing, turning, and backing into position to get logs. A skidding drum on the tractor, equipped with short lines to pull the chokered logs to the arch, fortunately renders additional maneuvering and coverage of the ground unnecessary.

According to the author's observations of tractors and arches in central Oregon about 20 percent of the area was deeply dragged by outcoming loads in main and side trails. An additional 25 to 30 percent was trodden once or several times by this heavy equipment in traveling and maneuvering off the trails. This was on gentle ground. On nearby sloping ground at least 10 percent additional area was covered in the unavoidable picking of special turning points on account of slope and the slumping downhill of the equipment. On this operation heavy tractors were used and loads consisted ordinarily of three 32-foot logs.

Destruction of young growth was practically complete on the dragged ground in main and side trails. Where the equipment traveled empty only once or twice over a piece of ground, seedlings up to 3 feet were mostly willowy enough to come up again unhurt after being flattened to the ground, with only moderate damage by breaking off of leaders; but saplings over 3 feet tall were crushed down permanently. Where the tractor turned sharply on one tread, as

was frequently the case in getting into position for skidding the logs to the arch, the soil was torn up and the damage was more severe. The area on which these observations were made was quite uniformly and abundantly stocked with seedlings and saplings before logging. It was estimated that after logging 60 to 70 percent of the ground was still stocked with seedlings and saplings that escaped or would survive logging damage.

Although a large portion of the area is trampled over rather roughly by the wide caterpillar treads of this logging equipment, a great deal of the small reproduction seems to survive such mistreatment. This fact and the possibility of confining tractor drivers to fewer routes make this method quite readily adaptable to minimum forestry.

MACHINE SKIDDERS

Steam logging has given way almost completely to tractors, although there are still a few scattered Clyde and Lidgerwood skidders in the region. Both machines are capable of excessive destruction, but where they have been used under very careful supervision, it has been possible to hold damage to a low enough degree to meet minimum requirements.

HORSE LOGGING

Direct skidding with horses does by far the least damage to the forest of any method of logging (fig. 9). Observations in Oregon show that the skidding trails under this method cover only about 5 percent of the cut-over area. Destruction of seedlings on these trails and such additional slight destruction as is caused in swamping represent the sole and practically negligible damage resulting from horse skidding.

Horses and high wheels are still used to some extent in parts of the region. Observations on one operation show that the ground covered by main wheel roads occupied about 7 percent and that covered by secondary wheeling about 10 percent of the area. Reproduction damage took place on this ground and also wherever logs were bunched. Under poorly managed wheel logging a larger proportion of the area than this may be scarred and more young growth destroyed.

It is characteristic of wheel logging to throw the slash into windrows paralleling the wheel roads. This increases the damage somewhat by covering up and smothering reproduction. Unless the timber stand is very dense, however, there will nearly always be enough reproduction free from or only lightly covered by slash, to permit the development of a minimum crop of young growth. Carried out with ordinary care, the use of horses and high wheels leaves cut-over land in acceptable shape for reasonable productiveness.

It may be said here that most of the timber of the northwestern pine region is ideally suited for animal logging. The size of the timber is convenient for handling. Slopes are ordinarily gentle or moderate. The typical ponderosa pine stands are open and largely free of underbrush, so that little swamping is required and maneuvering with horses is easy. By reason of the favorable topography, also, railroad construction is simplified and spurs can be frequent, thus permitting short skidding distances. In the case of the longer

draws or exceptional pieces of ground not practicably reached by railroad spurs, the logs can be brought in over chutes or roaded with tractors.

GRAZING ON CUT-OVER LAND

The grazing of livestock is an important industry in the northwestern pine region and not a little of the grazing takes place on cut-

FIGURE 9.—Horse logging does the least damage to young growth: *A*, Bunching logs with horses is a desirable preliminary operation for either horse or tractor skidding (F234849); *B*, high-wheel skidding with horses (F38500A).

over land. Where unregulated it may seriously operate against starting the second crop through browsing and trampling of seedlings. This form of damage is most apt to occur on bed grounds and driveways and on areas where no attempt is made to prevent overstocking and overgrazing of the range. Owing to a lack of supervision, overgrazing and its attendant evils are not uncommon on private cut-over holdings.

A study by Sparhawk (*29*) in central Idaho indicates that grazing damage is not ordinarily serious for seedlings more than a year

old, except on repeatedly used bed grounds and areas grazed with similar intensity. Of the seedlings less than 1 year old, however, 20 to 30 percent are apparently destroyed in all but the best regulated sort of grazing. It was found also that after seedlings became 3 years old and fairly well established, less than 1 percent a year was killed by grazing of moderate intensity, i. e., by grazing close enough to utilize about 75 to 85 percent of the palatable forage.

Certain range conditions on cut-over land, however, call for special attention. One of these is the natural reduction of available forage supply for a few years after logging caused by the masses of slash left on the ground. There must here be some decrease in the number of stock, if grazing is not to become concentrated in the openings with resultant overgrazing and inability of seedlings to become established. Again, in localities where loose, coarse-textured, granite soils occur on steep slopes the same number of stock cannot be carried after logging, without serious damage to reproduction, as on the more typically compact soils of the region. Here a reduction in the number of stock grazed is not only vital to the establishment of young tree growth, but it will also prevent deterioration of the range from the excessive trampling out of the herbaceous forage cover in the loose, sliding soil.

Under most conditions, quiet open herding, bedding down for but one night at each bed ground, and otherwise curtailing the trailing and rough handling of sheep on the range will keep to a minimum the damage to young reproduction and at the same time prevent wearing out of the range. Only in rare cases would it appear to be necessary, under minimum forestry conditions in the Northwest, entirely to exclude grazing for a time on cut-over land. One such case might be that of the loose, coarse-textured soils referred to where the land had already been badly abused by overgrazing. Under such conditions continued overgrazing would affect adversely not only timber production, but also water conservation in drainages which are depended upon for irrigation and other water use. Another case might be one where reproduction is absent or inadequate and seed trees have been unable to start reproduction. Under such extreme conditions heavy curtailment or exclusion of sheep grazing is indicated until a satisfactory minimum crop of seedlings 2 or 3 years old is established.

In general, it is safe to say that sheep grazing, if properly regulated, does but slight damage on cut-over land throughout most of the Northwest. Cattle and horse grazing does no harm worth mentioning. On the other hand, there are certain indirect benefits from the use of the range by livestock which should be mentioned. One of these is to prevent the accumulation of dead vegetation and thus decrease the fire danger. Light or moderate grazing does not remove enough of the ground cover to stop fires, but doubtless has an effect in reducing their heat and rapidity of spread and in making them easier to combat. Another benefit is the breaking up of slash and the scattering of the small pieces over the ground. This hastens disintegration and thus plays a part of some importance in the system of partial slash disposal.

Consideration of grazing on cut-over land would not be complete without mention of the possibilities of conflict between range and forest use of such land and how these two uses may be reconciled.

The stockman is likely to want to see the land cut clean and burned clean in order to insure maximum forage production and the utmost carrying capacity. The immediate money return from lease or sale of the land makes a strong appeal to the timberland owner, who on this account may be willing to accede to the stockman's demand for destructive burning. Although the practice is not general, a few timber operators in the region are actually burning their lands severely as a preliminary for use by the stockman.

Obviously such devastation of cut-over land in the interest of grazing is directly opposed to timber production and, furthermore, fails to recognize the possibility of making simultaneous use of the land to produce both forage and timber crops. In the open ponderosa pine forest, grass and browse continue to grow along with the trees, and the annual harvesting of the forage crop may proceed in entire harmony with the growing of the forest crop. Thus it is possible for the timberland owner to benefit by the current revenue from grazing, as indicated on pages 59–60, and at the same time continue to devote his land to the larger use of timber growing.

CONTROL OF INSECTS AND DISEASES[18]

Insects which are destructive to ponderosa pine forests are active primarily in virgin timber. The damage is caused by two classes of insects: (1) The bark beetles which kill trees by boring between the bark and the wood, and (2) the defoliators which seriously weaken or kill trees by feeding upon the needles.

A certain amount of damage by bark beetles takes place in mature stands at all times, but normally the killing of trees does not exceed 0.25 to 0.5 percent of the volume of the stand annually. At times, however, bark beetles multiply tremendously and create what are referred to by entomologists as epidemic infestations. Such epidemics may develop to large size and destroy a considerable percentage of merchantable timber.

During the past two decades there have been numerous examples of excessive insect damage in the virgin ponderosa pine stands of this region, and over 90 percent of it has been due to the activity of the western pine beetle (*Dendroctonus brevicomis* Lec.). Some of the heaviest losses have occurred in the Klamath Basin in southern Oregon, where continuous plot records kept by the Bureau of Entomology and Plant Quarantine since 1921 show a net depletion of 1.5 percent of the volume of the stand per year, or a total loss of about one-quarter of the standing timber over a 17-year period. On the Ochoco and Malheur National Forests in Oregon losses were light until 1931 when an epidemic following a heavy windfall reduced the volume of the stands on several hundred thousand acres by an average of 10 percent in 3 years' time. One area of 200,000 acres in this particular epidemic suffered a net loss of about 20 percent during this period. Equally heavy losses occurred about the same time in parts of the Klickitat Basin in Washington.

The mountain pine beetle (*Dendroctonus monticolae*) is usually less destructive to ponderosa pine stands than the western pine beetle, though frequently associated with it in epidemic outbreaks. How-

[18] Credit is due F. P. Keen of the Bureau of Entomology and Plant Quarantine for many of the facts on insect activity appearing in this section.

ever, when it becomes epidemic in lodgepole stands, it frequently spreads over into neighboring ponderosa pine. This has recently happened in connection with the severe lodgepole pine epidemic in the Bitterroot Valley in Montana, and has occurred in several other instances throughout the region.

Outbreaks of defoliating insects occur at sporadic intervals, and occasionally result in severe damage. During the period 1918 to 1925 an outbreak of the pandora moth (*Coloradia pandora* Blake) extending over thousands of acres of merchantable ponderosa pine on the Klamath Indian Reservation in Oregon resulted in considerable losses (*24*). Occasionally the pine butterfly (*Neophasia menapia* Felder) also becomes epidemic (*14*). It may defoliate extensive stands, but, unless the attack is very heavy or is repeated the following year, most of the trees recover. A few cases of extremely heavy defoliations have been known to kill outright large bodies of mature ponderosa pine.

Where insect epidemics threaten to destroy more timber than can be replaced by growth before logging takes place, control measures are ordinarily advisable. If incipient attacks are handled promptly and adequately, control work is usually successful. Under certain conditions, such as the beetle situation in the Bitterroot Valley in Montana where the protection of the ponderosa pine is complicated by immense surrounding areas of badly infested lodgepole pine, control measures may not prove to be economically feasible. As a single epidemic infestation may often include timber in both private and Government ownership, effective control work necessitates well organized cooperation on the part of the several agencies. The Bureau of Entomology and Plant Quarantine has worked out practical control measures (*11*) and if called upon will investigate the need for control and prescribe the measures best adapted to handle each specific situation.

As the western pine beetle confines its activity chiefly to older trees, residual stands of young trees left in selective logging are largely free from serious damage. The danger to reproduction and saplings from engraver beetles breeding in slash and the precautionary measures to be taken are discussed on page 18. After young growth and residual trees have recovered from injuries and exposures incident to logging, danger from beetles is usually negligible. Under minimum forestry practice, therefore, there is little likelihood that anything further will be required to avoid insect damage after the land has been cut over and is in a producing state. Such losses as do occur are usually of such a nature as to result in only a temporary set-back to continuous forest production.

Ponderosa pine is fortunately rather free from tree-killing diseases. So far as known, there are no serious native or introduced blight or rust diseases found on it within its natural range. Although several species of wood-decaying fungi attack it, it is on the whole but slightly infected with heart rots, the cull deductions due to rot being probably less than 3 percent of the total stand in this region. Moreover, damage from heart rot is concentrated in the old and overmature trees and the young trees are generally resistant until well past the age at which they will ordinarily be cut. A kind of mistletoe is found on ponderosa pine, forming dense witches' brooms. This

may weaken the tree's vitality, slow up its growth, and reduce its seed-producing ability, but rarely causes death. As mistletoe spreads to young growth from infected old trees, it would be advisable to include such old trees among those to be cut in logging operations.

EROSION AND STREAM-FLOW CONSIDERATIONS[19]

Erosion and stream flow are features which must be considered even in minimum forestry requirements. The first is closely related to the securing of reproduction, whereas the second is a public service which the timberland owner, as a part of retaining the good will of the public, cannot afford to overlook.

Throughout the region generally, forested watersheds are depended on to furnish water for irrigation and power. The mantle of trees, brush, and herbaceous vegetation covering the steep mountain slopes of these watersheds has a very important bearing on water supply and erosion. This plant cover checks rapid run-off and erosion and holds back a large portion of the water so that it sinks into the soil to reappear later in the season as stream flow. Any excessive disturbance of the forest cover such as results from destructive logging and burning of slash and overgrazing encourages rapid surface run-off and erosion with the attendant evils of reduced water storage and silting of reservoirs and streams.

In several cases in the region, particularly at Boise, Idaho, silting of reservoirs or dwindling of water supplies in recent years has caused considerable public concern and critical questioning of logging and grazing practices. In such important agricultural localities watershed values may easily outweigh timber and forage values, so that logging and grazing, unless they can be carried out conservatively, may have to be sacrificed to the welfare of the water user.

Fortunately, the harvesting of timber and use of the range can in most cases be harmonized with watershed protection. The essential requirement is to maintain a cover of vegetation that will hold the soil in place against surface run-off and aid in the absorption of water. This can ordinarily be accomplished by following with reasonable care the methods of cutting, logging, slash disposal, and grazing recommended thus far in this bulletin. By cutting to a given diameter limit, all the smaller trees and saplings are left on the ground. By careful horse or tractor logging, reproduction, brush, and herbaceous cover can be left largely undisturbed, and the cutting up of the ground surface by skid trails can be held to a minimum compatible with watershed protection under average conditions. The leaving of slash on the ground is in itself an effective measure for holding the soil in place and thus helping to prevent erosion.

In localities where the water supply comes from drainages characterized by loose, coarse-grained soil and steep slopes, additional precautions in logging will be necessary. Under these conditions horse skidding and the use of chutes will do the least damage to

[19]Acknowledgment is made to C. L. Forsling, former director, Intermountain Forest and Range Experiment Station, Ogden, Utah, for the greater part of the material on which this section is based.

soil surface, as well as to reproduction and undergrowth. On the steeper ground, tractors cause considerable dislodgment and slumping downhill of soil and consequent loosening and uprooting of vegetation. On steep ground also the deep skid trails caused by machine skidders and to some extent by tractors afford ready drainage channels for surface run-off, and these soon become well-developed erosion gullies.

In sections containing loose soils and steep slopes, range use calls also for special measures to meet the requirements of watershed protection. Trampling of livestock as it feeds and moves from place to place on precipitous ground causes loosening and downhill creep of soil, uprooting herbaceous vegetation and setting the stage for sheet and gully erosion. Such removal of vegetation reduces the rate of absorption by the soil of rain and snow water and naturally induces rapid surface run-off. Litter and humus, both of which also aid in the process of water absorption, are reduced as the vegetation becomes depleted and thus another element which helps to bind the soil and obstruct run-off is removed. Under such extreme watershed conditions as these, grazing obviously may have to be eliminated in some cases and restricted in others to very light use of the range.

GROWTH POSSIBILITIES ON CUT-OVER LAND

The manner in which growth takes place on cut-over land depends on the method of cutting practiced. Where clear cutting is done without seed trees of any kind, the future growth, coming from the advance reproduction and what few scattered saplings there may be on the ground, will not reach merchantable size, even on good growing sites, short of about 100 years. On the other hand, where a low grade of selective logging is practiced, it will be possible to leave a nucleus of small trees for making volume growth and for harvesting before the reproduction reaches merchantable size. The suggested minimum forestry practice of leaving the small trees will provide 4 to 13 trees per acre from 12 to 16 inches d. b. h. as shown in table 2, or roughly will reserve between 500 and 1,000 board feet per acre. Some stands will provide a few more trees and some a few less. Residual stands of this sort will produce on the average site, according to Meyer (*21*), a volume of about 2,000 board feet in 30 years and 2,800 board feet [20] in 50 years, amounting to an average annual growth of approximately 40 board feet per acre. As these yields will hardly justify logging, an operator desiring an early second cut may leave a residual stand of 1,500 board feet per acre and secure a volume of 3,300 board feet in 30 years and 4,300 board feet in 50 years. This is equivalent to an average annual growth of about 60 board feet per acre.[21] If the trees which are left are chiefly of the young, fast-growing type, these annual growth rates will be increased by 25 to 50 percent.

Studies of numerous old cuttings 15 to 30 years after logging, and in some cases more than 30 years, indicate that 50 to 160 board feet

[20] These figures are log scale, which means an overrun in these tree sizes of 20 to 25 percent.

[21] These figures do not include windfall and insect loss which is usually low in reserved stands containing only windfirm, thrifty, young trees of low insect susceptibility, and in any case will be more than compensated for by the above-mentioned overrun.

an acre is the usual range of mean annual growth that may be expected under intensive forestry. Areas studied by the author on which 2,000 to 4,000 board feet were reserved in cutting revealed an annual growth of 45 to 130 board feet per acre. Studies by F. S. Baker [22] in central Idaho indicated an annual growth of 50 to 120 board feet where stands up to 4,000 feet per acre were reserved. An unpublished Forest Service report by W. W. White gives 158 board feet an acre a year as the growth on a national-forest cut-over area in Montana where 7,500 board feet per acre had been reserved.

A particularly interesting measurement of yield of residual timber, because it was based on the volume actually removed in a second cut such as is recommended in this bulletin, was made by I. V. Anderson (*3*) in western Montana. In this instance a large operator relogged a sizable tract that had been logged originally 40 years previously by the unintentional selective cutting of that period. The residual stand left following the original cutting averaged 2,270 board feet an acre. Forty years later the second cut removed 4,120 feet per acre and left a small residual stand of 1,050 feet to the acre. The average annual growth made during the 40-year cutting cycle was 72 board feet an acre.

It is understood, of course, that realization of the yields here indicated is predicated upon following the measures of logging, slash disposal, fire protection, and seed provision outlined in these pages. These simple practices will not ordinarily produce forests capable of utilizing the full productive capacity of the land, but they will prevent forest destruction, with the attendant ills of waste land or land so seriously understocked with trees as to have no commercial timber value for a great many years to come.

PRACTICABILITY OF MINIMUM TIMBER-GROWING MEASURES

The practicability of measures designed to maintain minimum productivity on cut-over land depends primarily on their cost and returns and whether they can be practically carried out. Their feasibility has been proved by experience, and their general adoption is dependent on but a slight expenditure in the interest of better future returns.

The existing protection of virgin timber and going logging operations from fire is already reasonably effective, and in several instances effective protection is also being given to cut-over land. It only remains to extend equally high-class protection to the standing timber and logging operations of other owners and to all cut-over lands.

In the case of slash disposal, the proposed safeguards of cleared strips and intensive protection during the period of greatest risk have already been practiced with a great deal of success by several operators in Oregon and California.

Logging raises no important questions of practicability for the reason that all of the methods now used in the region can, with little cost, be conducted with sufficient care to preclude serious damage to reproduction and remaining trees.

[22] See footnote 4.

Leaving trees of seed-bearing size, likewise, has precedent in logging practice of the region. Logging cost studies indicate that many of the trees of seed-bearing size that should be left on areas deficient in advance reproduction are now being logged unprofitably, and that the size below which trees are logged at a loss will ordinarily leave sufficient trees for seeding purposes. Some operators in the region realize this and have been experimenting recently on their own account with selective logging.

COST OF MEASURES

Previous discussions have indicated that the cost of measures needed to maintain forest productivity will not prove burdensome. Recommended partial slash disposal, including intensive protection for 15 years after logging, can be effected at a total cost of 14 to 30 cents a thousand board feet, depending on extremes of conditions found in the region. Part of this cost is properly chargeable to the protection of the going logging operation which in all well-managed operations is provided by the owner regardless of whether or not he is cutting with a second crop in view. Such protection, therefore, should not be considered as an item of timber-growing costs. If the customary cost of insuring logging property against loss by fire could be separated from these figures, it would be found that the expenditure required purely for slash and the protection measures on cut-over land would reach but 10 cents or less a thousand board feet. The cost of protecting virgin timber ranges from 1.5 to 3.5 cents an acre a year over large areas, and on areas of special risk may average between 2 and 4 cents an acre.

Throughout much of the region no provision for seeding need be made under minimum forestry. Where some seed supply should be left in the form of small trees, this can be effected at an average cost of considerably less than 10 cents a thousand board feet of cut. For two specific localities where the costs were determined in detail, the outlay required to leave all trees 16 inches in diameter and less was 5 cents and 8 cents a thousand, respectively. Frequently, the diameter limit at which the greatest net return is made in logging may leave a sufficient number of seed trees per acre, and in such cases the cost obviously will be nothing.

As the existing logging methods and equipment do not in general require any restrictions, no additional costs due to timber-growing practice will be necessary on that score.

YIELDS, TAXES, AND RETURNS

Any estimate of the returns from the minimum measures here proposed would involve several considerations in the future which cannot be gone into with certainty at the present time, and yet it is possible to indicate in a general way what these are likely to be. The consideration of the yield to be expected has already been discussed on page 56. Another factor is that of future stumpage value. Although it is impossible to forecast this, the trend will unquestionably be upward. Even though the depression of the past few years has seriously reduced stumpage prices, there is nothing to indicate that the condition is permanent. With the shortage of

virgin timber definitely in sight and with new uses of wood products being developed, stumpage prices may reasonably be expected to increase.

One answer to the question of whether it will pay to return for a second cut on those lands where a diameter limit has been maintained is that it has paid in several instances already. In these cases the owners found it worth while to extend part of their operations in virgin timber to adjoining cut-over lands in order to harvest the residual trees left in early logging 30 or 40 years previously. Although such instances of recutting at present are entirely incidental to logging in neighboring virgin timber, they indicate the feasibility of the second-cut proposal. An example worthy of mention is one in western Montana in which a large operator relogged an area which had been cut 40 years previously by the unintentional selective logging of the early days. The first operation in 1887 removed an average of 8,020 board feet per acre and left 2,270 feet to the acre in residual trees. The second cut in 1927 yielded 4,120 board feet and left 1,050 board feet an acre on an area of about 2,000 acres (*3*). It may be added that the region as a whole contains thousands of acres logged 25 years ago or earlier, that now actually offer a worth-while second cut.

Another consideration with regard to costs is taxation. One of the obstacles to timber growing in the past has been the failure of State tax laws to distinguish between cut-over land that was burned and devastated, and that which was left in fair shape for reforestation. Oregon, Washington, and Idaho have enacted forest-tax laws which provide for this in varying degree by allowing owners whose holdings qualify as "reforestation lands" to benefit by a low annual tax on these lands while the timber is growing, deferring an equitable yield tax until the timber is harvested. The Oregon law provides for a flat tax of 5 cents an acre, and the Idaho law for a flat valuation of $1, making the rate there about 3.5 cents an acre. In both of these States the yield tax is equal to 12.5 percent of the value of the timber to be harvested. In Montana, available figures show taxes on ponderosa pine cut-over lands to average about 10 cents an acre. Although the forest-taxation study recently completed by the Forest Service [23] has concluded that the yield tax is not the most desirable form of forest taxation, it is a distinct improvement over the old system.

It is well to keep in mind that the outlay for slash disposal and protection of logging equipment, ranging from 14 to 30 cents a thousand board feet, is incurred only on the portion of the timberland being logged during the year. On the other hand, the expenditures for taxes and fire protection, which are assessed annually against the whole timber property reach only about 5 to 13.5 cents an acre. The total is not great and all of the costs may properly be regarded as operating charges to be written off against the annual income of the business.

In addition to the major income from harvesting the timber crop, a small annual income is available from grazing on cut-over and

[23] FAIRCHILD, F. R. THE FOREST TAXATION INQUIRY. U. S. Dept. Agr., Forest Serv. 60 pp. 1933. [Mimeographed.]

virgin forest lands. The grazing rental now being received on large-sized tracts of private cut-over land throughout the region ranges from 5 to 12 cents an acre. Over much of the ponderosa pine country the grazing rental will offset for the owner the greater part of, if not the entire annual outlay for, taxes and fire protection on his cut-over land.

From the standpoint of returns, therefore, it would seem to be good business for the larger owners, with 25 or 30 years' cut ahead of them, to reserve the small trees that will be left by the diameter-limit cutting in the virgin timber here proposed, whether or not these are required as seed trees. The second cut thus made possible has the advantage of extending the life of the plant and the business. For such corporations as may own sufficient timber to operate continuously on a sustained yield, i. e., whose annual cut is balanced by annual growth, there is, of course, no question as to the desirability of leaving the rapidly growing young trees for a return cut. Such operators should aim higher than mere productivity and adopt measures calculated to produce full timber crops as described in the latter part of this bulletin.

GENERAL CONSIDERATIONS.

In addition to the above considerations of costs and returns and feasibility of the measures, there are certain intangible features connected with keeping cut-over land productive. Among these may be mentioned the greater value that cut-over land, with thrifty reproduction and scattered trees on it, will have as compared with burned and denuded land. Although such reproducing land seems to have little additional sale value now, young second growth is bound to be an asset in the future, whether the owner expects to hold the land himself or to dispose of it. The end of the virgin timber supply is no longer a matter of conjecture, but a recognized fact in the life of many of the sawmill plants of the region. In some localities this will become a reality in much less than 30 years. To the smaller owners who cannot look forward to a second cut, but who wish to leave their cut-over lands productive, this offers a reasonably safe possibility of realizing a return on the small investment that may be required in carrying out the minimum measures. Aside from this, a definite commitment on the part of the owner to leaving cut-over land in a green and productive condition and to conserving watershed values has the intangible value of securing for him the good will of the public. This is beginning to mean a great deal, and will mean more with the rapidly developing consciousness on the part of the people regarding the value of forest cover, not only for producing wood but also for controlling erosion and stream flow.

It will bear restatement that selective logging, although not always essential to minimum productivity, is highly desirable for most operators. The practice will cost the operator very little and the assurance of an early second cut may make it possible for him to retain ownership of his cut-over land. In any event, thrifty, small trees, which it would not now be profitable to log, will not be sacrificed. The proposed measures for keeping cut-over land productive have actually been in use in one form or another either unconsciously or

by design. They are, therefore, not to be regarded as untried or theoretical proposals. Modifications of the measures, in fact, are now being used successfully by several of the large operators in the region. Putting these measures into practice systematically and consistently means no more than the application to the whole region of measures that have already been found desirable and profitable by some owners. They can be applied by the operator with but slight additional cost and no serious changes in existing logging practice.

MEASURES NECESSARY TO PRODUCE FULL TIMBER CROPS

CONDITIONS SUITABLE FOR INTENSIVE FORESTRY

For those owners who may be prepared to undertake more intensive measures in timber growing than the first steps discussed in the preceding pages, and for others who may wish to investigate the possibilities of such practice on their holdings, it is desirable to outline methods which will attain more nearly the full productive capacity of the land. Such full utilization of the growing power of forest land is only assured by producing fairly complete crops of timber, as compared with the partially stocked stands that may be expected to result from the minimum measures.

The owner who has enough virgin timber to run his mill until the regrowth on his lands will supply his annual cutting needs continuously is naturally in the best position to practice intensive forestry. The degree to which he will find the practice profitable will depend upon the suitability of his lands for growing timber, or what the forester calls site quality. Where the site is good, owing to favorable soil and climatic conditions, the rate of growth will be sufficiently rapid to provide an attractive margin of profit between costs and returns.

In a region with differences in climate and soil as great as those between southern Oregon and western Montana, site quality is bound to vary tremendously. Where the growing season is long, not too dry, and not too frosty, and where the soil is reasonably good, ponderosa pine attains fairly rapid growth in height and diameter, and produces attractive yields per acre. Where the growing season is relatively cold and short, or where the soil is poor, regardless of climate, the trees are shorter, the growth slower, and the yields per acre are less. In view of the extent of the region and the variation in site within it, it is not practicable in a work of this sort adequately to prescribe methods of site classification. Qualified consulting foresters are available to determine the site quality of lands for those operators who wish to have this done.

Exceedingly large returns in the growing of timber cannot be promised, but neither is that possible in the business of manufacturing lumber. Reasonably profitable employment of capital is a possibility here which merits close investigation on the part of those who are in the lumber business. For forests in Federal and State ownership there is no question, of course, of the advisability of practicing measures which will utilize the full productive capacity of the land.

THE MEANING OF FULL PRODUCTIVITY

In even-aged stands, full timber crops develop only from full crops of reproduction. To meet the standard of full productivity, therefore, it is necessary to have a fairly complete cover of advance reproduction on the ground before logging. The reproduction must be well distributed and abundant enough to produce a clean stand of trees of good quality at maturity. The number of seedlings per acre that will produce such a stand varies a great deal, owing to the irregularity of spacing in nature in which dense patches are often intermingled with scattered reproduction. In planting practice in this region the Forest Service uses 800 to 1,000 transplants to the acre, but this number is sufficient only where spacing is fairly even. To secure comparable results through the haphazard distribution in nature requires approximately three or four times this number of seedlings to the acre. In timber of uneven-aged composition, the standard of full productiveness is met if the ground is fairly completely occupied with a mixture of seedlings and saplings and scattered residual trees left in selective logging.

CHARACTER OF THE FOREST TO BE DEALT WITH

The virgin ponderosa pine forest characteristically presents a picture of open, uneven-aged stands containing generally many yellow-barked mature and overmature trees, some darker bull pines or younger trees, and here and there dense groups of seedlings or saplings. An inconspicuous and often unseen part of the picture is presented by the quite uniformly distributed suppressed seedlings struggling along in the grass under the mature trees. Although this latter reproduction is small and suppressed, it has great power of recovery and, after the mature trees are cut, usually develops into a dense stand of vigorous second growth.

The outstanding characteristic of the virgin forest, perhaps, is its uneven age. From time to time individual old trees drop out here and there by death through insects, windfall, fire, and other causes (*22*, *36*) and seedlings and saplings fill in the openings. All ages from seedings to veterans 500 or more years old are represented in the stand. The distribution of the age classes, however, is far from regular, and except for the reproduction represents more often a condition of more old trees than young ones.

On 40 acres of sample plots in eastern Oregon (*36*), on which the ages of all trees above the reproduction class were counted, the age distribution was 9 percent by number of trees in the class 20–100 years, 22 percent in the class 100–200 years, and 69 percent in the classes 200–600 years. Results of an age-class compilation made by E. L. Kolbe of the Pacific Northwest Forest Experiment Station on typical stands in seven localities in the region, in which all trees 10 inches d. b. h. and larger were classified into immature, mature, and overmature trees are shown in table 7.

Although the immature trees generally comprise the smaller proportion of the stands, there are usually enough of them, if combined with thriftier individuals of the mature class, to afford an adequate reserved stand under intensive selective cutting.

TABLE 7.—*Average number of immature, mature, and overmature trees per acre, 10 inches d. b. h. and larger, in typical ponderosa-pine stands*

Locality and area of sample	Immature[1]	Mature	Overmature	Total
	Number	*Number*	*Number*	*Number*
Deschutes, 40 acres	7	18	8	33
Klamath, 188 acres	11	9	4	24
Fremont, 64 acres	11	10	5	26
Malheur, 16 acres	10	20	8	38
Wenatchee, 11 acres	13	6	(2)	19
Snoqualmie, 14 acres	7	22	(2)	29
Columbia, 9 acres	1	11	(2)	12

[1] The immature trees or bull pines on these areas ranged from 10 to 28 inches d. b. h. They were classified in the field into Dunning tree classes 1, 2, and 6 (illustrated in fig. 15 in the appendix). The maximum diameter of mature trees on these areas was 46 inches and that of overmature trees 62 inches.

[2] Mature and overmature trees were not segregated on these areas. Thus, the last three figures in the "Mature" column include also overmature trees.

Ponderosa pine is also found in even-aged second-growth stands. In localities where early cutting was carried on, are many thousands of acres of cut-over land covered with young, even-aged stands now 35 to 50 years old. Particularly good examples are to be found near Baker and Klamath Falls, Oreg., in the vicinity of Boise, Idaho, and Missoula, Mont., and along the edge of the farming country in northern Idaho and eastern Washington. Older even-aged stands occur in small bodies rather infrequently throughout the region.

The process and the difficulties of obtaining reproduction have been described in the first part of the bulletin. The important facts are that good seed crops come infrequently and are largely depleted by rodents, and that seedlings suffer a heavy mortality from drought and other causes. Thus a crop of reproduction is established only through the slow accumulation of surviving seedlings from several periodic good seed crops. It requires usually 15 to 25 years for a complete cover of seedlings to become established even where seed supply is ample.

GROWTH PER ACRE UNDER INTENSIVE FORESTRY

In the virgin forest there is practically no net growth per acre. Trees that drop out through death from time to time ordinarily balance the annual growth.

In even-aged second-growth stands within the region, the average annual growth per acre of five bodies of timber was found to be 125, 151, 153, 198, and 300 board feet (Scribner Decimal C rule), respectively. These figures were obtained by strip cruises in stands 100 to 160 years old and 20 to 100 acres or more in area. In a study of normal yield based on 83 ideally stocked sample plots in northern Idaho, C. E. Behre found at 100 years of age an average annual growth per acre of 135, 298, and 436 board feet (International rule)[24] for poor, medium, and good sites (*5*).

In stands left after selective logging, the individual trees make a noticeably increased diameter growth. This acceleration is the result of liberation from competition and may amount to fully 2 or 3 times the growth rate made by the same trees before logging (fig. 10). This vigorous increased growth may continue for 35 or 40

[24] The International rule gives values about 25 percent greater than the Scribner rule.

years or more, falling off gradually as the understory of saplings develops into vigorous young pole stands, which in their turn then offer strong competition to the reserved trees.

The increased growth obviously causes each tree to lay on considerably more volume than is added to an equal-sized tree in a dense stand. Because of the comparatively few trees to the acre left in ordinary selective logging, however, the total annual growth

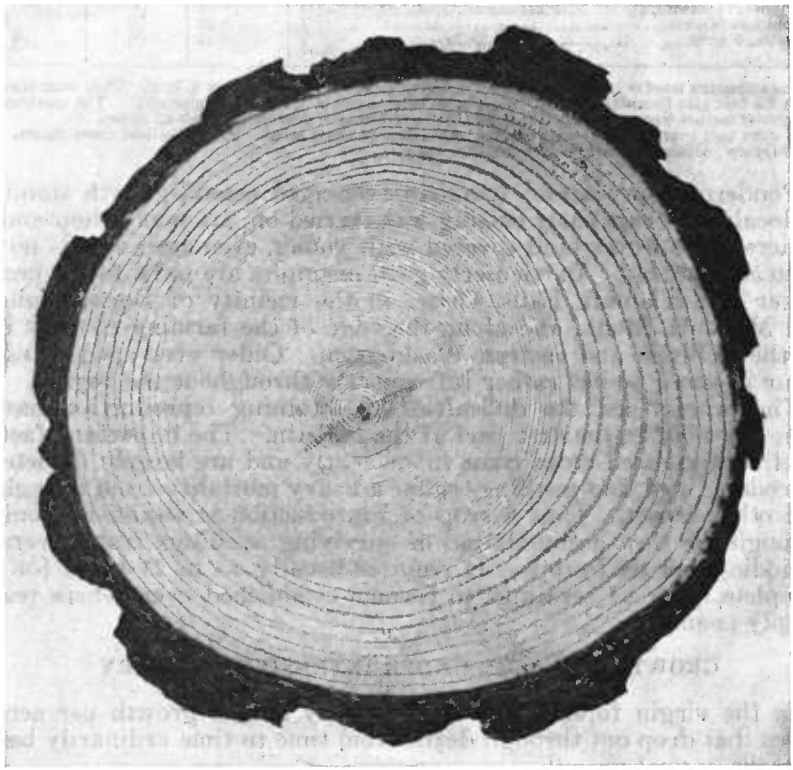

FIGURE 10.—Cross section of young ponderosa pine tree left standing in selective logging. The wide annual rings represent the accelerated growth made since the logging operation.

per acre is not great. The exact amount of growth per acre depends on the number, volume, and vigor of the remaining trees and the quality of the site. As would be expected from the later gradual decline of stimulated growth, the growth per acre varies also with the length of the period following cutting over which the total growth is averaged. A reserve stand of 3,000 board feet of thrifty trees on a good site, for example, may show a mean annual growth of about 80 board feet an acre up to 30 years after cutting, but only 72 board feet for the period up to 60 years following cutting.

The most recent and thorough study of growth following selective cutting has been conducted in eastern Oregon and Washington by Meyer (*21*) of the Pacific Northwest Forest Experiment Station. A total of 179 plots containing about 5,600 residual trees were taken

in old, selectively logged areas up to 60 years old. The plots represented residual stand conditions resulting mostly from the unintentional selective cutting of the early lumbermen. Although light culling of the best trees sometimes left a considerable volume, the remaining stand naturally was not reserved with any growth or second-cut objective in view. Thus these residual stands contained both old and young trees which were not equally well fitted to make increased growth following logging. In view of this, the resulting growth shown by these old cuttings is not as great as will be obtained where only young, thrifty trees are reserved under intensive forestry practice. Based on the measurements taken on these plots, Meyer prepared a series of growth tables from which the data in table 8 have been condensed.

TABLE 8.—*Volumes attained and average annual growth in average ponderosa pine timber (site IV) of eastern Oregon and Washington 30 to 50 years after early, unintentional selective logging*

Volume per acre left in cutting (board feet)	30 years after cutting		50 years after cutting	
	Volume per acre [1]	Average annual growth per acre	Volume per acre	Average annual growth per acre
	Board feet	*Board feet*	*Board feet*	*Board feet*
1,000	2,300	43	3,200	44
2,000	4,000	67	5,200	64
3,000	5,400	80	6,700	74
4,000	6,700	90	8,100	82
5,000	7,800	93	9,500	90
6,000	9,000	100	10,800	96
7,000	10,200	107	12,100	102

[1] Volumes are in Scribner Decimal C rule for trees 12 inches d. b. h. and up.

As table 8 shows, the average annual rate of growth per acre on the old, selectively logged areas ranged approximately from 40 board feet, where a residual volume of 1,000 feet per acre was left, to 110 board feet where a residual volume of 7,000 feet was left. It should be pointed out that these figures represent growth rates obtained in culled stands on land of average timber-growing capacity for this region (site IV). Meyer found that on better land (site III) the yields were higher by 7.5 percent at 30 years and by 12.5 percent at 50 years than those given in the table. He also found that wherever individual plots contained residual stands made up almost entirely of young, thrifty trees, the growth rates increased 25 to 50 percent over the average values appearing in the table. Although the figures here given do not include deduction for loss through insects and windfall, this is more than compensated for by the 20- to 25-percent overrun which results in computing log-scale volumes in trees of this size. Thus under intensive practice where marking is done to insure that only the fast-growing trees are reserved, the growth rate will appreciably exceed the best shown in the table and may on the better sites approach 200 board feet an acre a year.

Those who are interested in applying growth rates in detail are referred to Meyer's discussion (*21*) which goes into the subject very thoroughly for all kinds of sites and stand conditions.

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As already described, areas on which 2,000 to 4,000 board feet were reserved in cutting revealed an annual growth of 45 to 130 board feet per acre. Studies by Baker[25] in central Idaho indicated an annual growth of 50 to 120 board feet where stands up to 4,000 feet per acre were reserved. Three permanent sample plots also in central Idaho,[26] in which an average of about 3,200 board feet were reserved, gave a net annual growth of 136 board feet per acre. It is interesting to note that the average annual loss on these plots amounted to 20 board feet per acre over a period of 18 years. An unpublished Forest Service report by W. W. White gives 158 board feet an acre a year as the growth on a national-forest cut-over area in Montana where 7,500 board feet per acre had been reserved. In these cases the period since cutting ranged from 15 to more than 30 years. As discussed on page 59, a second cut by a private operator in western Montana in which 2,270 board feet was reserved showed an average annual growth of 72 board feet per acre during the 40 years following cutting (*3*).

THE PROPOSED INTENSIVE MEASURES

The measures here proposed for producing full timber crops are based largely on the experience gained on the national forests of the region, where intensive forestry has been practiced for 25 years, and on the results of research. As will be seen below, the measures for cutting and slash disposal represent a very distinct intensification of those outlined for crude forestry. Measures in the interest of grazing and of watershed protection are of as high a standard under minimum as under intensive timber growing and are, therefore, not treated again here.

Summarized, the intensive measures discussed in detail in the following pages are as follows:

METHODS OF CUTTING

Selective cutting, reserving anywhere from 15 to 50 percent or more of the volume of the stand for return cuts is the method proposed for general practice on both private and public forest land. Thrifty trees best fitted to make increased volume and quality growth and to seed up the ground are carefully selected and marked for reservation before logging.

Clear cutting is suggested only for spots in the stand, or for occasional larger areas, where the stand is composed almost exclusively of old, decadent trees incapable of an increased rate of growth on release. In such cases dependence for the second crop must be placed mostly upon advance reproduction.

SLASH DISPOSAL

Flexibility in slash disposal is recommended, with piling and burning of all slash as the method to be used under most conditions, and partial disposal (as described for minimum measures) on parts of the operation least susceptible to fire danger.

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[25] BAKER, F. S. See footnote 4.

[26] From an unpublished report by the Intermountain Forest and Range Experiment Station.

FIRE PROTECTION

Fire protection measures are practically the same for intensive as for crude forestry, for the reason that nothing short of the strictest measures against fire are acceptable for any degree of timber growing in ponderosa pine, where trees and reproduction must always be protected before, during, and after logging.

METHODS OF LOGGING

If used with reasonable care to preserve reproduction and remaining trees, all logging methods described as permissible under minimum measures may be employed under intensive forestry. Greater precautions must be taken, however, to confine maneuvering of tractors and arches to a smaller proportion of the logged ground.

INSECT AND DISEASE CONTROL

Intensive forestry in ponderosa pine requires definite provisions for insect control beyond that attained by minimum measures. This means marking of insect-susceptible trees in selective cutting and also the treatment of infested trees on all parts of the timber holdings whenever epidemic conditions threaten. Similarly intensive forestry requires the removal, as a sanitary measure, of trees that are badly infected with mistletoe and fungus.

METHODS OF CUTTING

SELECTIVE CUTTING INDICATED AS BEST METHOD

Experience in the cutting of timber in the northwestern pine region began over 50 years ago in private timber and about 25 years ago in the national forests. This experience has ranged from clear cutting through various degrees of unintentional selective logging on the part of private operators to an intensive form of selective cutting in Government timber. From the results of this experience foresters have found that selective cutting of the type used in the national forests, or some modification of it, is the method best adapted for intensive forestry in ponderosa pine timber.

Selective cutting means simply cutting a carefully selected part of the stand and leaving a portion for an early second cut. The owner is not only concerned with making a present profit, but also in investing enough in reserved trees to insure profitable repeated cutting on the same ground. As practiced in ponderosa pine timber on the national forests and Indian reservations, the method in its best form removes about three-fourths of the merchantable volume of the stand, and depends on the growth of the remaining trees of merchantable size and smaller to permit recutting over the area every 40 or 50 years. This is not the same thing as "high-grading" the forest by deliberately taking only trees of the best lumber grades regardless of the growth possibilities of the remaining crop.

ADVANTAGES OF SELECTIVE CUTTING

There are several noteworthy advantages of selective cutting in the ponderosa pine forest. The more important of these are:

(1) To cut over the timber property rapidly in order to harvest, as early as possible, the old and decadent trees, and thus convert an

old-growth forest from a condition of no net growth to a young forest capable of full productivity.

(2) To make a higher profit per acre and per thousand board feet by leaving the trees which ordinarily have low realizable values but which are capable of making satisfactory growth.

(3) To create a growing stock having early harvest possibilities as a second cut by leaving thrifty, young, saw-log trees which are now at the stage of making their most rapid volume growth.

(4) To provide, by reserving some of the middle-sized trees, a possibility of clear lumber in the second cut (a product which will be highly valued when logging in second-growth stands will yield chiefly common grades of lumber).

(5) To offer opportunities for the rapid removal of old decadent trees which are most susceptible to beetle attack and for the salvaging of infested trees during the logging operation.

CONDITIONS TO WHICH ADAPTED

The conditions which lend themselves best to selective cutting are primarily those in which the forest contains an abundance of young trees in the stand (fig. 11). To afford a nucleus for laying on increment sufficient to provide for an early second cut, there must be available to leave not less than 2,000 board feet per acre of thrifty trees. These stand conditions exist to a reasonably favorable degree throughout most of the region.

As ponderosa pine stands are not always uniform, conditions within the larger stretches of timber will be found here and there which are not adapted to selective cutting. An example of this is the occasional body of open-standing, decadent old trees with a noticeable absence of poles and bull pines. It would be better forestry in such cases to depend largely upon advance reproduction for restocking the ground and to retain only sufficient overmature trees to seed up the blank spaces. Trees of low quality may well be used for the latter purpose.

Even in stands where a full cover of seedlings and saplings is established, selective cutting, because of the advantages previously stated, is decidedly advisable.

From the early national-forest cuttings, and especially from the older private cuttings, some of which are already 50 years old, it is possible to get a very good idea of how the forest crop grows and is renewed under selective logging. On the areas studied, the remaining trees over 12 inches in diameter numbered, for the most part, from 8 to 20 per acre evenly scattered and in groups. Since cutting, a few trees then less than 12 inches in diameter have grown to merchantable size and accordingly increased the reserved stand. Liberated from competition, the trees have grown rapidly and greatly increased their volume. Surrounding these trees and in the openings between them, the ground is covered with a dense stand of saplings, which have developed chiefly from advance reproduction and on the older cuttings are now 30 to 40 feet tall. The general picture presented is that of a two-storied forest, in which the upper story is made up of scattered or grouped reserved trees occupying roughly one-fourth of the ground and the lower story is formed of dense young growth, more or less uniformly distributed. Rarely, where there are sufficient small trees under 12 inches in diameter, the

FIGURE 11.—Character of ponderosa pine stands: *A*, Typical virgin condition with more mature and overmature trees than young ones, and with ordinarily a good scattering of small suppressed seedlings on the ground. (F158295.) *B*, Less common many-aged stand condition with saplings, poles, and middle-sized trees intermingled with veterans. (F271818.) *C*, Rare and highly productive even-aged stand of the kind that will be common in the future when present, young second-growth reaches maturity. This stand is about 100 years old. (F25207.)

two-storied effect is broken by middle-sized trees and this, of course, represents a more desirable type of selection forest.

VOLUME TO CUT AND LEAVE

In selective cutting certain factors influence the volume of timber to cut and leave. These are chiefly size and health of trees, composition, and volume per acre. As timber varies in size and composition over a tract, it is not wise to set a fixed proportion of the stand to be reserved on each acre or other small unit of area. Where the average diameter is high and the stand is pure pine, the volume that can be left with profit may be comparatively small. On the other hand, where the average diameter is small and where there is a large admixture of other species, a fairly large proportion of the stand may be reserved. Under various stand conditions, good selective cutting may reserve anywhere from 15 to 50 percent or more of the volume of the original stand (fig. 12). In order to make the second cut worth while and not to have too long a cutting cycle,[27] a minimum of about 2,000 board feet in trees more than 12 inches in diameter should be left. The average should be well above this amount. In selective cutting on the national forests of the Northwest the remaining stands range ordinarily between 2,000 and 7,000 board feet per acre. The larger reserves include an appreciable volume of merchantable timber of medium size, in addition to the smaller thrifty trees.

In the last few years a form of very light selective cutting has been proposed in which only about 50 percent of the volume of the stand is logged in the first cut. The purpose is to log only the trees which yield the highest values in lumber grades and on which the logging and milling costs are lowest. This proposal has been made in the belief that quick and big returns will be made per acre and remaining stands will be left in such condition as to yield the earliest possible second cut.

SELECTION OF TREES TO BE LEFT

Among the qualities which govern the selection of individual trees to be left are capacity to make rapid growth, seed-bearing ability, and ability to withstand windfall. To these should be added size, as it affects logging and milling costs and lumber grades.

In view of the variation of stand conditions, nothing short of actual marking of the trees selected to be felled is effective as a method of reservation.[28] Mechanical reservation by cutting to a fixed diameter limit fails to meet the requirements satisfactorily for the reasons that appear in the following discussions.

The chief characteristics of a tree that the timber marker should consider are its age, size, crown, vigor, bark, seeding capacity, degree of injury, and liability to windfall and other loss (*38*). The tree should be young enough to make profitable volume growth and

[27] The cutting cycle is the period between cuts on the same piece of ground. With a small reserved stand the period of return, or the cutting cycle, will be long; with larger reserved stands the cutting cycle will be correspondingly shorter.

[28] Long experience in the Forest Service has shown that marking the trees to be felled, rather than those to be left, is the better practice. Mechanically, the process is to mark each tree with two blazes, impressed with the owner's stamp, one at the base of the tree and one at breast height. A special type of marking ax has been developed for this purpose in the Forest Service.

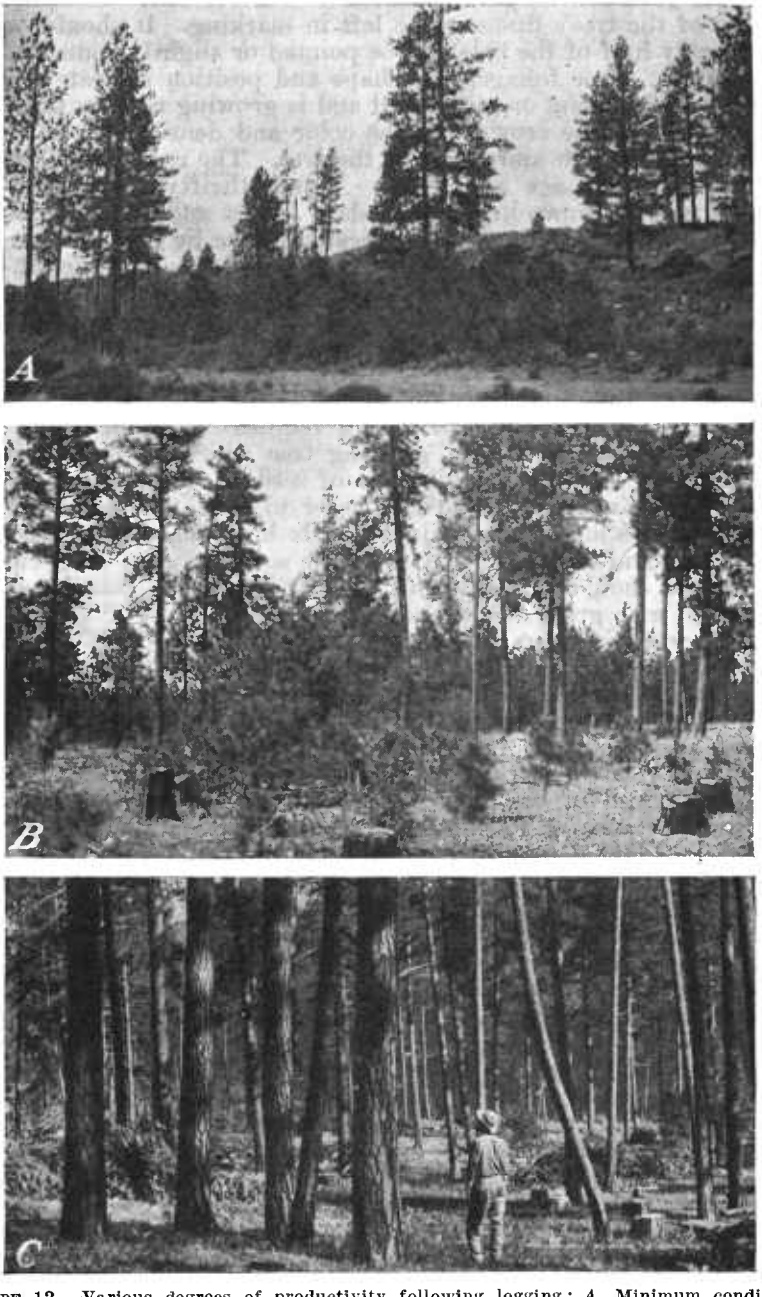

FIGURE 12.—Various degrees of productivity following logging: *A*, Minimum condition with low order of stocking of smallest trees and reproduction (F158297); *B*, intermediate condition following selective logging leaving trees less than 16 or 17 inches d. h. h. (F228486); *C*, desirable productivity with heavy reserved stand of thrifty trees of all sizes (F86471).

produce good seed crops. The crown of a tree offers the best indication of the tree's fitness to be left in marking. It should occupy preferably half of the bole and be pointed or slightly rounded, with dark-green, dense foliage. Its shape and position indicate whether the tree is dominant or suppressed and is growing rapidly or slowly. The height of the crown and the color and density of the foliage indicate the health and vigor of the tree. The color and thickness of bark indicate age and vigor. Young thrifty trees have bark that is reddish brown in ridges or dark yellow and deeply furrowed. The tree's seeding capacity is indicated either by cones on the tree or by the collection of old cones lying on the ground under it.

Badly injured or deformed boles are undesirable in reserved trees. Thin, open crowns of pale-green foliage or very small, tuft-like crowns are worthless in trees to be left for seeding purposes. Crowns badly infected with mistletoe, which sometimes present a very dense and luxuriant appearance, are also worthless for reserved trees. Thin, scaly bark of a reddish or purplish hue indicates an old and very slow growing tree which, as a rule, is unprofitable to leave for the purpose of seeding or increased growth. Great height must be avoided in order to safeguard against windthrow. Trees more than 24 inches d. b. h. in the northern part of the region and 30 inches d. b. h. in the southern part bordering on California should generally not be left, since such diameters ordinarily go with great height and old age.

A tree-classification scheme which has proved very useful in marking trees for selective cutting in California pine forests has been devised by Dunning (*13*). The system should serve equally well in most of the pine territory of the Northwest. Its purpose is to aid in recognizing individual capacity of trees for reservation and its distinctive feature is that it integrates all of the characteristics described in the preceding paragraphs into seven age-thrift classes. Because of its importance to timber markers the classification as adapted to the Northwest pine region is included in the appendix (p. 88).

It should be the aim of good marking and cutting practice to remove all decadent, malformed, and diseased trees, whether merchantable or not. These trees are ordinarily not good seed producers, nor are they capable of making good growth, and they occupy valuable ground space upon which healthy, wood-producing young trees should stand. If diseased, they may be a source of infection for the young remaining stand. Some of these trees, more particularly the very defective old white firs, may not contain enough merchantable material to cover the costs of logging and milling. The cost of felling and leaving them on the ground, however, will amount to only a few cents a thousand feet, which will be more than repaid by increased growth on the sound, high-quality timber reserved for the second cut.

To obtain the greatest amount of accelerated growth in reserved trees, attention should be given not only to age, crown, and vigor of the trees, but to their position as well. Liberation from competition of neighboring trees is, of course, the basis for stimulated growth through the enlarged soil moisture supply made available to the remaining trees. The effort, therefore, should be to free each

tree as far as that is possible, leaving a fairly even distribution of the remaining stand rather than a groupwise arrangement.

The principal form of loss in reserved trees is windfall. According to sample-plot studies (*35*) the volume lost from windfall is about twice that from all other causes. Although violent windstorms may occasionally take a heavy toll in selectively cut timber, the destruction is usually restricted in area and rarely felt again in the same locality. Normally severe winds, on the other hand, may throw some trees every few years, and it is such loss that should be guarded against as much as possible by the timber marker. To withstand windfall, a tree should not have great height or an excessively large or top-heavy crown. It should not be located in very shallow soil. The best type of tree is one of medium height and pyramidal crown, with good root anchorage and with its center of gravity in the lower half of the tree. Marking should be heavy in danger spots, such as, for example, saddles and soggy ground, and correspondingly light on neighboring sheltered spots, in order to maintain the desired volume in reserved trees. Particularly bad spots can be recognized by the down trunks of trees thrown in previous windstorms.

SLASH DISPOSAL AND FIRE PROTECTION

Slash-disposal and fire-protection measures for intensive forestry rest upon the same basic facts as do the measures intended merely to keep forest land at minimum productivity.

So far as the general fire-protection system is concerned, it is desired to repeat that only measures of the highest standard should be considered under any form of forestry. Advance reproduction is so vitally important to perpetuation of the forest and fire so inimical to its welfare for a considerable period of years before, during, and after logging, that nothing short of this will pay, whether an owner is committed to a low or a high order of timber growing. This means the application of strict and thorough-going measures for prevention, quick detection, and prompt suppression. Fire protection measures based on this premise, as already outlined (pp. 29–34), serve equally well for growing full timber crops.

The method of slash disposal recommended for minimum forestry was partial disposal. This means the complete removal of slash on certain strips of high risk, and intensive patrol of the cut-over area during the decade or more required to reduce the remaining slash menace. Although this treatment gives a reasonably good degree of protection, and may be used under some conditions of intensive timber growing, it falls short of the protection desired where the risk is great or where there is a particularly high investment in remaining trees. Under such conditions, piling and burning of slash on the entire cut-over area is advisable.

PILING AND BURNING SLASH

Piling and burning, as described on page 16, is a method by which all slash is piled as the logging progresses and the piles are burned at a time of the year, usually late fall, when fire will not spread over the ground. It has been the standard method of slash dis-

posal used by the Forest Service in ponderosa pine logging for 25 years. As a result of this experience there is available a well-developed technique dealing with size, shape, and location of piles, as well as time and manner of burning (fig. 13). See appendix (p. 88) for the essential steps in piling and burning.

Carefully carried out, piling and burning results in the most effective clean-up of slash and the least damage to reproduction and remaining trees possible under any form of slash disposal. That successful execution of the method is practicable, is shown on vast areas of national-forest cuttings by the uniform presence of young growth and the absence of debris. Studies of such areas reveal

FIGURE 13.—Slash disposal under intensive forestry. Piled slash ready for burning in a heavy reserved stand. (F86468.)

negligible damage to advance reproduction and only rarely the killing of small trees.

It is of the utmost importance to burn piled slash promptly and completely in the short period usually favorable to burning. Lack of skill, care, and good judgment in carrying out piling and burning will yield results as disastrous as under any other system. As the most critical conditions prevail at the time of burning, the greatest failures occur during that process. These failures are chiefly in misjudging weather conditions and burning when it is too dry or windy, in igniting contiguous piles at the same time or too many piles at once, and in failing to postpone burning when the needle litter has dried out until it carries fire over the ground. The immediate and obvious effect is the escape of fire, with the greater or less destruction that inevitably attends uncontrolled burning. This can largely be avoided by employing dependable and experienced brush burners and having competent foremen to give them the closest supervision. If the burning of slash piles scorches neighboring trees, if fire runs from one pile to another through reproduction, if fire leaps now

and then from a burning pile into the tops of poles and saplings, all the effort of doing a good job of selective logging and careful piling of slash is of no avail.

FLEXIBILITY IN USE OF SLASH-DISPOSAL METHODS

Although piling and burning will probably be advisable for the most part where full timber crops are to be grown, there will be situations in intensive practice justifying the use of other methods. Where the risk is not great, for example, either because of climatic or topographic conditions, ease of protection, light cutting, or an open stand yielding only a small amount of slash, it may prove entirely feasible to employ the method of partial disposal with intensive protection. In such instances a flexible slash-disposal policy should be carried out—piling and burning where required and partial disposal where the less expensive method will serve the purpose.

The method described in the first part of this bulletin (p. 27–28) as swamper burning in piles is closely related to piling and burning and may very advantageously be substituted for it during part of the year.

Certain well-defined conditions will always demand piling and burning under intensive forestry. Into this category fall areas where fire-starting agencies are most prevalent, such as recreational centers and zones paralleling roads and railroads; areas of rough relief or hot, south exposure, where fire spreads most rapidly and is, if at all, controlled only with the greatest difficulty; small isolated cuttings for which it would not pay to set up an intensive system of protecting remaining slash; larger areas where, for one reason or another, an owner may not desire to assume the task or responsibility of intensive protection for 10 years, or where he may find it impracticable to do so. Under conditions such as these, complete removal of slash by piling and burning will in the long run prove the cheapest and safest procedure.

For larch-fir timber and other mixtures found in the pine region, piling and burning in general offers the only safe method. Partial disposal may be resorted to only where stand conditions are most favorable for the control of fire. With trees of all sizes intermingled and with branches extending from the tops to the ground, as they do in this type, fire starting in remaining slash readily becomes a conflagration.

PROTECTION ACCOMPANYING AND FOLLOWING INTENSIVE SLASH DISPOSAL

Although fire protection of cut-over land upon which piling and burning has been done need not be so intensive as that on areas treated by partial disposal, the situation after cutting is always such as to require definite protective measures. With complete disposal of logging debris, the protection of cut-over ground approaches the relatively simple practice employed in the virgin forest. Records show that fires have burned over only 0.05 percent annually of all the pine cut-over lands of eastern Oregon and Washington upon which slash was piled and burned. It is important, however, to realize that grass and other vegetation are more abundant on cut-over land than in virgin timber and dry out sooner, creating a flashy

fuel through which fire travels rapidly. Reproduction is destroyed by a grass fire, whereas older trees are rarely killed outright by this type of blaze. Because of these considerations there is really more at stake on cut-over land than in virgin timber, and consequently need for special attention in protection plans.

Protection during the logging operation is as vitally important with piling and burning in use as with any method. Slash is everywhere present on the ground during the fire season, either in piles or in the process of being piled. As rigorous and complete provisions for prevention, detection, and suppression are needed as in partial disposal.

Closely related to slash disposal as a feature of protection is the matter of snag felling. It was seen in the discussion of minimum practice (p. 25) that complete snag felling is not generally considered necessary except on areas of greatest fire danger. These include routes of travel and zones surrounding points where people live, work, or take their recreation, where the possibilities of fires starting are greatest. Another case calling for felling would be concentrations of snags on ridge tops where winds would easily carry sparks into adjoining drainages. If complete felling over the entire cut-over ground is desired, it will clearly give the utmost refinement in security against danger from snags and can be done for about 10 cents a thousand board feet of cut.

COST OF SLASH DISPOSAL AND FIRE PROTECTION

Costs per thousand board feet cut for piling and burning slash over the entire area, for felling snags on strips and zones of special risk only, and for effective protection during and after logging are as follows:

Piling and burning all slash	$0.35 to $0.75
Snag felling on portion of area	.01 to .03
Protection during logging	.05 to .06
Protection of cut-over land after complete piling and burning[29]	.02 to .04
Total	.43 to .88

Variations in the cost of piling and burning slash throughout the region are due to character of topography, to size, density, and composition of timber, volume of cut, and other factors. In their exhaustive study of pine slash disposal, Munger and Westveld (*23*) found that, using wages prevailing in 1927, 1928, and 1929, the following costs of piling applied: For stands under 8,000 board feet per acre, 70 cents per thousand feet of logs; for stands of 8,000 to 12,000 feet, 55 cents; for stands of 12,000 to 15,000 feet, 40 cents; for stands of 16,000 to 20,000 feet, 35 cents. These were average costs; under the easiest conditions the cost was 30 cents. The average cost of burning was about 5 cents.

Obviously the total costs will be reduced where a combination of piling and burning with partial disposal can be effected, the reduction depending upon the area and volume of timber treated by each method. If it were found feasible, for example, to handle one-third of a tract by partial disposal with intensive protection and two-thirds

[29] In order that the costs of protecting cut-over land under intensive disposal may be compared with those of partial disposal, these figures are based on a 15-year period.

by the pile-and-burn method, the cost, assuming an average cut of 15,000 feet an acre, would total only 35 to 68 cents per thousand as compared with the above figures.

For effective protection of virgin timber and the second crop already on the ground in the form of advance reproduction, owners should figure on spending 2 to 4 cents an acre a year as described in the first part of the bulletin. Present expenditures of private agencies, ranging from 1.5 to 3.5 cents an acre, provide against fire loss to merchantable timber, as has been noted, but in many cases they do not safeguard the advance seedling growth upon which production of full timber crops depends.

In the consideration of timber-growing costs, which at best owners may regard as high enough, it is important to point out that the above cost statement includes not only slash disposal proper, but also measures for protecting standing timber, camps, and logging equipment, for which an operator spends money regardless of whether he disposes of slash or protects his cut-over land. If the customary expenditures for insuring logging property against fire loss in this way were segregated, the total amount shown above would be considerably reduced. Highest assurance both of safety for remaining trees and continued productivity of timberland justifies the costs under intensive forestry.

PROTECTION AGAINST INSECTS AND DISEASES

Although the insect problem is practically eliminated where light residual stands are left, as under minimum cutting measures, beetle losses may become serious in the heavier reserve stands left under intensive forestry. The danger, however, can be largely reduced by taking the precaution in advance of logging to mark for felling the trees most susceptible to bark beetle attack. The type of tree most frequently attacked by the western pine beetle, which has already been described as the most prevalent and destructive beetle in ponderosa pine during normal and early epidemic conditions, was found by Person (*27*) to be characterized by poor vigor and slow growth. Susceptible trees were for the most part the larger, older ones having poorer types of crowns. The indicated prescription, therefore, would be to mark these trees for cutting and to leave the younger and thriftier ones with pointed crowns that are ordinarily free from attack by the western pine beetle, at least during the early stages of epidemics. Such a procedure not only lessens the danger of insect losses, but also fits in with good marking practice which aims to reserve trees best suited to make increased growth.

The avoidance of injury to standing trees during logging, and the proper handling and disposal of logging slash according to methods previously discussed are measures which reduce the danger of beetle attack. Injury to young trees and the dropping of tops or the piling of slash in reproduction thickets are particularly conducive to insect damage and should be avoided. Piling and burning of slash is effective if it is done before the infesting insects emerge, but because of the fire danger early summer slash cannot be burned soon enough to prevent beetle emergence. In such cases leaving slash exposed to the direct rays of the sun is an effective method of destroying a high percentage of the engraver beetles that breed in it.

Unusual conditions may at times give rise to quite severe insect losses in reserved stands. H. Weaver (*33*) reports a case on the Klamath Indian Reservation in Oregon in which a thrifty reserve stand on a good site was heavily attacked by the western pine beetle in 1932 following a combination of unfavorable climatic conditions and fresh windfalls. Control measures were found necessary to halt the damage. Other cases have been reported in the region where following severe and prolonged drought or light surface fires, insect damage in reserve stands has mounted rapidly and control measures were necessary. In general, however, under the best selective cutting practice, insect losses in reserved stands are not apt to be serious. Person found an annual loss from bark beetles of 13 trees over 12 inches in diameter per square mile, on five national forest areas in California which had been logged 20 years previously. That this is close to what might be expected in the northwestern region is shown by records of an annual insect loss of 19 trees per square mile in 10 years after cutting on three large permanent sample plots in eastern Oregon.

Under intensive forestry practice, the insect problem in stands which have been cleared of beetle-susceptible trees through selective cutting should not be a difficult one to handle. Normally the losses will be light, but if windfall or other special conditions favorable to an epidemic should occur, the situation must be watched closely and incipient outbreaks promptly controlled.

Ordinarily little serious trouble will be encountered from other insects in the ponderosa pine region. From time to time, however, cone borers operate on an extensive scale and may destroy almost entire seed crops. No method of control is known at present. The occasional outbreaks of the pandora moth and the pine butterfly have already been referred to (p. 54).

Although ponderosa pine is little troubled by tree-killing diseases, it will pay to take some steps in prevention where the aim is to produce full timber crops. These are called sanitation measures in national-forest cutting and involve the removal during logging of badly diseased or mistletoe-infected trees to prevent early infection of second growth and remaining trees. There will be little of this to do as a rule in pure pine stands. In mixed stands, however, where white fir is usually heavily infected with rot, more felling of diseased trees will be required. Cutting of diseased trees over the entire area being logged may ordinarily be effected in this region for 3 to 5 cents a thousand feet of cut. Not only do the badly rot-infected trees spread disease to the younger reserved timber, but they take up valuable space that should be occupied by thrifty, fast-growing trees. Moreover, the little annual growth that such defective veterans make is more than offset by the rate of deterioration of their heartwood caused by the rot.

METHODS OF LOGGING

The rather complete discussion of logging methods and damage in the first part of the bulletin emphasized the fact that the logging systems now used in the region do not on the whole do sufficient damage to render them incompatible with minimum timber-growing requirements. There is no reason why these same methods should

not be permissible where full timber crops are to be grown, provided they are used under stand conditions where they will do a minimum of damage, or where additional precautions can be taken to lessen the damage to young growth and reserved trees. As illustrated by national-forest cutting, such steps can be taken without imposing costly or impossible restrictions upon private logging practice.

Tractor logging, for the most part, can readily be made to meet the requirements of intensive forestry. It has been seen that tractors with fair-lead arches, as now used in private logging, cause 30 to 40 percent damage to seedling and sapling growth. Similar damage results from direct skidding with tractors not equipped with skidding drums and from the use of tractors with high wheels. This damage is somewhat too severe for forestry aimed at producing full timber crops. For such intensive forestry it is absolutely essential that a detailed logging plan be made in advance of cutting. Precautions should be taken, for example, to select proper tractor roads and suitable locations for bunching logs; to fell timber toward the roads so as to avoid unnecessary turning and rolling of logs; to reduce to a minimum unnecessary swamping in connection with locating tractor routes; and to greatly curtail wheeling and maneuvering of arches. One of the most effective measures in reducing damage will be the general use on tractors of drums and short skidding lines. As tractors confine their destruction to young growth without doing material damage to small trees, carefully executed tractor logging is well suited to selective cutting, where dependence is placed more on remaining trees than upon advance reproduction.

Horse logging causes the least destruction of young growth and but a negligible damage, or none at all, to remaining trees. As already explained, the convenient size of timber, the absence of underbrush, the favorable topography, and other factors render animal logging ideally suited for the pine territory. As in the use of tractors, however, a detailed logging plan made in advance of cutting is essential.

PLANTING

Good forestry practice in the United States everywhere aims to obtain restocking after logging by natural reproduction, rather than by the artificial method of planting nursery-grown seedlings. As compared with natural restocking, planting is an expensive operation and is only justified where natural regeneration is impossible or too slow. Fortunately, the abundant advance reproduction ordinarily found in the ponderosa pine forest of this region makes recourse to planting necessary only in rare cases.

A clear-cut instance of the need for planting is on devastated land. Where severe fire has destroyed all or most of the remaining trees and reproduction, as it often did in broadcast burning of vast slashings some years ago, the prospect of the area becoming productive by natural processes in any reasonable period is hopeless. Planting offers the only prompt means of getting a crop started on such land. A careful estimate made some years ago by Federal, State, and private agencies revealed somewhat over a million acres in the region which were so badly devastated as to need artificial reforestation. This included severely burned areas which appeared to have no chance of restocking naturally short of 20 or 30 years.

The only cases calling for planting in careful logging and slash-disposal practice would under ordinary circumstances be areas devoid of advance reproduction and apparently incapable of regenerating naturally within a reasonable time after cutting. If such areas occur on highly productive ground, planting would seem to be justified to establish young growth promptly and utilize the full growing capacity of the land. Artificial sowing of seed, which costs a good deal less than planting of nursery-grown stock, is still in an experimental stage owing to the depredations of rodents.

APPLICATION OF INTENSIVE MEASURES IN LARCH-FIR STANDS

In contrast to the open character of ponderosa pine timber, the larch-fir stands, found usually as smaller bodies within the pine type, are dense and contain trees of all sizes and ages, with the young trees, poles, and saplings outnumbering the mature trees. The trees in mixture are chiefly western larch, Douglas fir, white fir, lodgepole pine, and occasionally a few ponderosa pines.

Selective cutting is the recommended method of harvesting these mixed stands. In the form of a practical culling of the stand, it is also the practice the operator now follows naturally for economic reasons. Because of small demand and low market value, he logs only the best larches and Douglas firs and a few other desirable trees. The remaining stand after such selective logging comprises a fairly intact forest cover of mature trees of white fir and younger trees of all the species in mixture. Under intensive forestry some additional steps should be taken systematically to select the trees to be cut and left, and also to eliminate the old white firs which are always badly rot-infected in this region.

Piling and burning is the safest method of slash disposal under intensive forestry in this timber type, with the possibility of partial disposal only where conditions are most favorable for the control of fire. Owing to the contiguous position of saplings, poles, and large trees, the crown canopy is in many places continuous from the ground to the tops of the tallest trees. For this reason the location of piles and the process of burning demands even more care than that required in pine timber, in order to prevent flames leaping to the low branches of small trees and from these into the crowns of adjoining larger trees.

Logging methods recommended for intensive timber growing in pine stands are equally applicable to larch-fir timber. Owing to the larger number of saplings and small trees, however, additional precautions in the handling of equipment may be necessary to keep damage to a minimum compatible with the production of full timber crops. Horse skidding in combination with chutes and railroad spurs, or with tractor hauling over main-line trails, may be mentioned as least destructive to remaining small trees.

The complete fire-protection measures recommended for pine timber are also applicable to larch-fir stands.

PRACTICABILITY OF GROWING FULL TIMBER CROPS

In many localities within the wide boundaries of the ponderosa-pine region of the Northwest, with its varied topography and climate, the conditions for forest production are reasonably attractive

and offer in the practice of forestry a commercial opportunity worthy of serious investigation by timber owners (fig. 14).

The items which enter into the investigation are the same here as in any forest region. They are briefly: (1) Productivity of

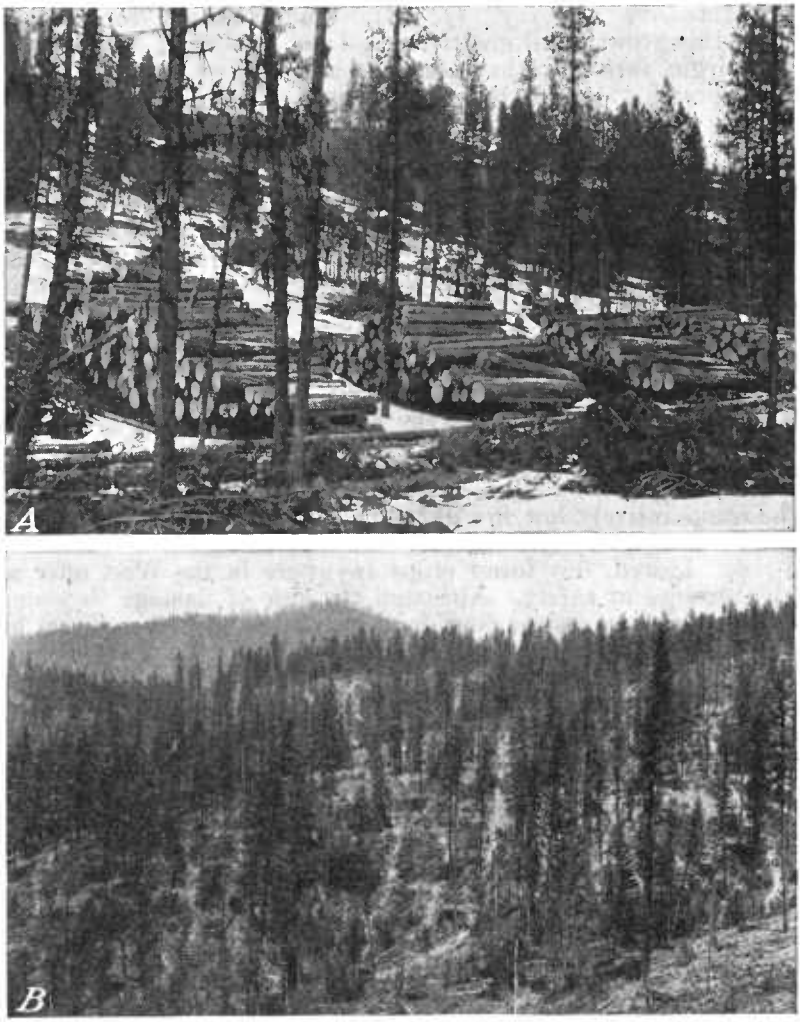

FIGURE 14.—Cut-over land like this is a valuable asset: *A*, Selective logging here yielded a heavy initial harvest and still left enough thrifty young trees for a second cut (F173170); *B*, suitable small and medium-sized trees are nearly always available for reserved stands (F210983).

land; (2) safety of investment; (3) cost of producing crop; and (4) yields and returns.

PRODUCTIVITY OF FOREST LAND

Careful examination by qualified men is necessary to determine what the growth possibilities of any timber holdings are and

whether they will justify intensive forestry as a paying business. It may be said, however, that over much of the region the timberlands at the lower elevations, now in the hands of private owners, produce fairly attractive yields per acre. The yields that may be expected are indicated in the section entitled "Growth per Acre Under Intensive Forestry" (p. 63). Under proper forest management this growth will greatly exceed the amount of wood grown in the virgin forest or that resulting merely from crude timber-growing practice. As has been shown by Kirkland (*31*), the volume and quality of production can easily be built up by increasing the amount of growing stock, as is done under properly executed selective cutting. Ponderosa pine stands long enough under management to provide illustrations are not yet available, but two examples of natural second growth will serve to indicate the increased yield possibilities. An even-aged stand of young timber in Oregon, 120 years old and covering about 70 acres, cruised 38,250 board feet an acre, International log rule. A similar stand in northern Idaho, 130 years old and occupying 200 acres, gave a yield of 26,200 board feet to the acre by the same rule. The yields in both these stands, in spite of the lack of fire protection, are still large enough to surpass by at least a third the average yields of virgin timber in these localities.

SAFETY OF INVESTMENT

The comparatively low fire danger and ease of protection in the ponderosa pine territory make this kind of pine timber a reasonably safe risk. Indeed, few forest crops anywhere in the West offer as great assurance of safety. Although the risk of damage to young growth is always a serious consideration, this is greatly reduced by intensive slash disposal and protection measures. That the cost of adequate fire protection is not prohibitive to the practice of forestry in ponderosa pine is shown by the experience of the Forest Service and the private timber-protective associations. This assumes full cooperation by the public as contemplated in the Clarke-McNary law. The risk of loss from insects and disease is also low and the cost of control in second-growth and selectively cut stands is ordinarily negligible.

COST OF PRODUCING THE CROP

Perhaps the greatest obstacle to the growing of timber is the viewpoint of the lumberman that reforestation of cut-over land calls for an entirely separate financial operation from that of the rest of his timber business. Whereas the costs of operation, insurance, and protection of the logging and manufacturing parts of the business are normally charged off each year out of current revenue, young growth necessary to keep the business going permanently is looked upon as a long-term investment, the annual tax and protection costs of which must be carried at compound interest until the crop becomes ripe for harvesting.

Unquestionably the compound-interest method of financing and accounting has its rightful use where a body of timber is acquired and held as a speculative investment, or where an isolated piece of bare land is planted for holding until the crop matures. In the

case of a permanent lumber business, however, where growing and cutting of timber may go on hand in hand continuously, such a financial theory is entirely impossible, just as it would be in any other permanent business undertaking. Its application, in fact, would in a short time lead to the elimination of any continuous industry.

The growing of timber where it is at all profitable must be as inseparably a part of the lumber business as are logging, manufacturing, and selling the crop, and the annual costs must be handled in the same way, i. e., by deducting them from the current revenue. The objection may be made that although harvesting, manufacturing, and marketing the crop are clearly annual operations, growth must proceed for about 100 years before a crop is matured. The bare fact that trees take a long time to reach maturity, however, fails to tell the whole story. In reality a timber property that is adequate to supply permanently the needs of a mill actually does grow an annual crop. An example will illustrate this readily. If a timber property under forest management be assumed to be divided into 100 blocks or compartments, each block differing in age by 1 year from 1 to 100 years, each will yield at maturity a harvest equal to the annual cutting needs of the mill. Obviously by this system a crop ripens each year. As each year's cut represents the annual growth in 1 block for 100 years, or the growth of 1 year in the 100 blocks comprising the entire timber property, the forest managed in this way actually produces an annual crop.

With the growth laid on each year over the whole tract equaling the volume of the annual cut, there seems to be no sound reason why the costs of securing and maintaining the growing crop, which are incurred annually, should not be deducted from the returns of annual cutting, in accordance with generally accepted principles of good business management.

The cost of producing the crop involves—aside from overhead, interest on investment, and such items common to any business—chiefly outlay for protection and the special measures recommended for full timber growing. Operators already pay for protecting both their virgin timber and the improvements and equipment used in logging, regardless of whether they are interested in forestry. Although forestry practice will require an additional outlay for protection as previously discussed, this should not be prohibitive in the light of increased yields to be expected. Special precautions in logging will cost but little and may be more than balanced by the advantages gained from the required logging plan prepared in advance of cutting. The leaving of small trees in selective cutting will at most cost but a few cents a thousand feet of cut and will usually result in a saving over the system of cutting all-sized trees regardless of the effect on profits.

The problem of taxation, although more of an obstacle to the practice of forestry than to other business, is not believed to be insurmountable. Certainly no one device such as the forest-yield tax will completely solve the problem. Its final solution rests upon an overhauling of the whole tax plan, including reorganization or consolidation of local governments where necessary. A progress report of an exhaustive study of the forest taxation problem by the Forest Serv-

ice [30] discusses the various possible methods of taxation. The conclusion is reached that, although the forest-tax plan now in effect in Oregon, Washington, and Idaho is a big advance over the old system, a better system termed "partial timber exemption plan" holds greater possibilities of success.

The public and lawmaking bodies everywhere are bound shortly to see the desirability of tax relief in its relation to the advantages of full timber production. Clearly, it is an asset to the community to have taxpaying forest industries maintained permanently, as compared with the liability of tax-delinquent lands and absence of milling and manufacturing plants.

YIELDS AND RETURNS

The main income from forest management comes, of course, from the harvesting of timber products. As has been stated, increased timber yields are a natural sequence to the leaving of an adequate growing stock as is done under intensively conducted selective cutting. Along with increased growth comes a shorter period of return for second cuts. Under minimum forestry, average annual growth of approximately 40 to 80 board feet per acre is indicated where only the smaller trees are left in logging. With the reservation of the maximum number of young and thrifty trees under intensive forestry, average annual growth will about double these figures.

A form of income possible under intensive timber growing that should not be overlooked is that resulting from thinnings in young second-growth stands. Already in some parts of the United States small trees comparable in size to thinned material carry a market value for pulp and other uses. With the increased utilization possibilities for small trees to be expected in the future, thinnings should become practicable throughout much of the country as they have been for a century or more in Europe. Although the amount may not be great, the income from thinnings will come at intermediate periods in the growing of a timber crop when such revenue will serve acceptably in helping to defray carrying costs.

An additional form of income from ponderosa pine timberland is that offered by its excellent forage resources. Not only does the pine region produce an abundance of range plants highly palatable to sheep and cattle, but regulated stock grazing throughout most of the timber-crop rotation is entirely compatible with intensive forestry. The current annual return of 5 to 12 cents an acre from this source may offset in part at least the annual outlay for taxes and fire protection on cut-over land.

The owner who is considering the growing of full timber crops will naturally be concerned with the future demand for lumber and other wood products. It is, of course, impossible to make long-time forecasts of lumber needs and consumption. The most recent estimate made by the Forest Service is that present saw-timber consumption is about five times the present growth (*31*). At this rate virgin timber supplies cannot last indefinitely. Despite the downward trend in lumber consumption, it seems safe to assume that the

[30] FAIRCHILD, F. R. See footnote 23.

increasing shortage in saw timber will make for a reasonably favorable market for lumber by the time residual stands left in present-day selective cutting are ready to be logged.

PLAN OF MANAGEMENT FOR PERMANENT TIMBER PRODUCTION

The growing and harvesting of full forest crops as a long-time business enterprise require a thorough plan of management to make sure that the various and interdependent steps are carried out systematically and that a sustained yield will be kept up through the years. The important items are: (1) To see that the proper blocks as to age, area, and volume of timber come up for cutting each year; (2) to see that the annual cut does not, without the owner's knowledge, exceed the annual growth; (3) to employ the form of cutting calculated to give the best results in rapid increment from reserved trees, or prompt and full restocking of young growth; (4) to provide the logging and slash-disposal methods most suitable to the conditions in any given area; and (5) to afford the required degree of fire protection for various parts of the timber property. The preparation of a management plan that will fulfill these specifications involves a careful timber and topographic survey of the holdings, and particularly a technical study of the growth rate, site qualities, age classes, character of the virgin and immature timber, fire and other risks, and factors influencing logging. The plan should, of course, provide for the most economic order of cutting with regard to maturity and marketability of the constituent bodies of timber, postponing those which for one reason or another might better await a more favorable period of utilization. The scheme should also insure correlation of the engineering with the technical cutting features of the operation, with a view particularly to economy and the avoidance of unnecessary repetition in the laying and taking up of railroad spurs. Such a plan will not only furnish the guidance necessary for carrying on a sustained-yield operation—its very preparation will in large measure answer the questions of feasibility of intensive forestry for the timber property under consideration.

A feature of the management plan calling for special mention is that of sustained yield as related to the size of the timber holdings and capacity of the owner's mill. Given a sufficiently attractive rate of growth, conditions best suited to the practice of sustained-yield forestry will be found where operators own enough standing timber to keep their plants going until second growth will supply their annual cutting needs continuously. Where owners have not enough timberland for this purpose and are unwilling to reduce their mill capacities to the volume of timber that can be grown annually on their own lands, it will be necessary to purchase logs to cover the deficiency. An alternative might well be worked out whereby private owners may, through long-term agreement, obtain the blocking out, together with their own lands, of sufficient neighboring private, State, or Federal forest land to meet the sustained cutting needs of their mills. This could be done in the case of both large and small operations, and would mean the management of whole working circles, irrespective of land ownership, for single operating concerns in the interest of continuous forest production.

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APPENDIX

DUNNING'S TREE CLASSIFICATION

The following is a condensed statement of Dunning's tree classes (*13*) as adapted to ponderosa pine in the northwest. The several classes are illlstrated in figure 15.

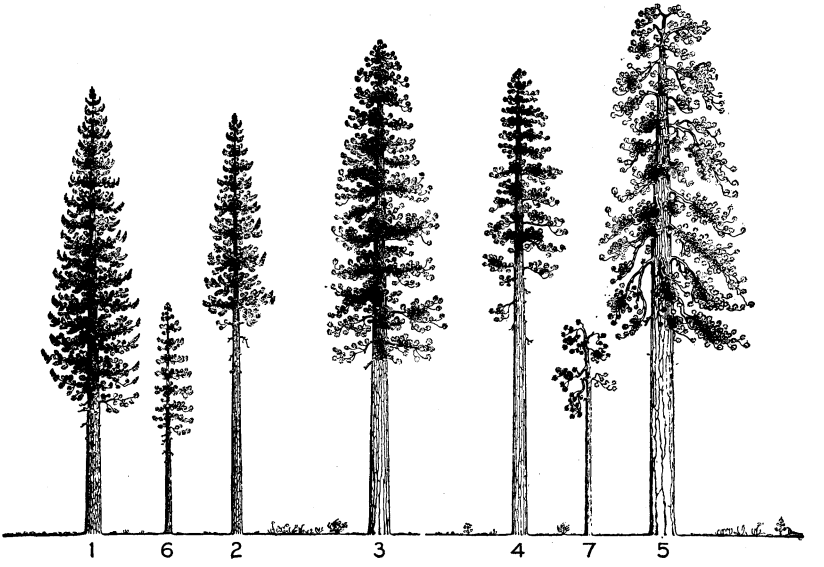

FIGURE 15.—Dunning's crown diagram for use in marking trees for selective cutting. Classes 1, 2, and 6 represent young or thrifty trees; classes 3 and 4, mature trees; and classes 5 and 7, overmature trees.

Class 1 trees grow most rapidly and are least liable to loss from windfall and insect attack. They are good seed bearers. They carry comparatively low lumber values. These trees should practically always be reserved.

Class 2 trees make fair growth. They are somewhat liable to loss. They are poor seed bearers, but promise improvement after release. They may ordinarily be retained, but should be cut in preference to the larger class 1 trees and if there are sufficient other thrifty trees to make up the reserve.

Class 3 trees grow rather slowly, but can be expected to increase in value without great risk of loss. They are good seed bearers. It is not advisable to retain too many of them, but where sufficient class 1 trees are lacking, where good seed trees are needed, or where an early second cut is desired, there should be no hesitancy in leaving class 3 trees.

Classes 4 and 5 trees produce practically no growth. Their liability to loss is high. Their retention involves a large and rather insecure investment in high-quality timber. They should nearly always be cut.

Classes 6 and 7 trees are usually too small to be merchantable. The class 6 trees make fair growth and promise later development if released. They bear practically no seed. They should be retained if relief from competition is insured by removal of neighboring trees, otherwise cut if merchantable. The class 7 trees are undesirable from every standpoint and should always be cut if merchantable.

ESSENTIAL STEPS IN PILING AND BURNING SLASH

PILING

The essential points to be observed in piling slash with a view to satisfactory results are briefly as follows:

(1) Limb up all tops, so that branches may be placed compactly on piles. Parts of branches larger than 4 or 5 inches in diameter should be chopped off

and left out of piles along with other large material which will not burn up completely.

(2) Build piles in an orderly fashion with the larger branches on the outside. Make the piles compact, so that they will shed rain and snow and will burn readily after storms.

(3) Piles should ordinarily be 6 to 8 feet in diameter and 5 to 6 feet high. Larger piles may be made in large openings and smaller ones in small openings. If piles are too small, they burn with greater difficulty under adverse weather conditions, and by reason of their greater number appreciably increase the cost of both piling and burning.

(4) Locate piles far enough away from reproduction and remaining trees to prevent damage from heat and leaping flames. If possible the distance should be at least 15 feet from low-crowned, young trees. Prevent the spread and hang-over of fire by keeping piles away from down logs and felled snags. If piling is done after logging, locate piles in skid trails and roads as much as possible.

(5) Always pile slash while it is green to insure better clean-up and lower cost than is possible in handling dry slash.

BURNING

In order to do the burning successfully, the following points should be observed:

(1) Burning crews should consist of 4 or 5 men in charge of an experienced and careful foreman. Enough crews should be used to be sure of cleaning up all the slash in the short period usually suitable for burning.

(2) Lighting of the piles should only be done by responsible members of the crew who can be depended upon to use good judgment in applying the torch.[31] The rest of the crew should tend the burning piles, so as to make sure of a reasonably good clean-up and prevent the spread of fire from the piles.

(3) If the piles are close together and burn too freely, light only every second or third pile, and burn the others later or on another day. Never touch off at one time more piles than can be tended safely under the existing weather conditions.

(4) Burn piles across or against the wind and ignite them on the leeward side. On slopes start burning at the top and proceed downward. Never light a pile from which wind-blown flames may reach a nearby tree.

(5) Leave unburned the occasional pile standing so close to trees or reproduction as to endanger them if burning is attempted. It is better to leave a pile now and then than to destroy young growth.

(6) The key to successful burning is the selection of exactly the right time to do it. When conditions are right for burning, equipment should be ready and crews available on call. Postponement of a day or two may mean increasing the cost or preventing a clean-up of the job, by reason of early change to dry or extremely wet or snowy weather.

(7) Whenever conditions become dry enough for fire to spread, as they sometimes do during the middle of a warm day, discontinue burning temporarily until conditions are right. Under such conditions burning operations may sometimes be transferred to less dry north slopes, or may in some cases have to be done at night.

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[31] A convenient brush-burning torch used by the Forest Service in Oregon and Washington consists of a kerosene chamber made of 3-inch pipe, 16 inches long, fitted with a screw cap at one end and a reducer at the other. From the latter projects a ½- or ⅝-inch pipe, 34 inches long, into which is inserted a cotton wick. This torch holds about a quart of kerosene which will last from 4 to 6 hours. Slightly modified forms of this torch are used by the Forest Service in other sections of the pine region.

SUMMARIZED COMPARISON OF PROPOSED MINIMUM AND INTENSIVE MEASURES

FIRE PROTECTION

Minimum measures	Intensive measures
Complete fire protection of highest standard before, during, and after logging.	Complete fire protection of highest standard before, during, and after logging.

SLASH DISPOSAL

Partial disposal by burning only on strips along lines of high risk and leaving slash elsewhere. Slash will be disposed of on about 20 percent and left on about 80 percent of cut-over land. Special fire protection for 10 to 12 years until slash menace reduced by decay is necessary part of this method.	Piling and burning all slash except on some portions of area where risk is low where partial disposal may be used.

CUTTING METHODS

No cutting restrictions where sufficient advance growth is present. Where advance growth is insufficient leave all trees 16 inches d. b. h. and less or, on the average, about 10 trees per acre between 8 and 16 inches.	Selective cutting, reserving 15 to 50 percent of volume of stand. In restricted cases of small bodies of old, decadent trees incapable of making increased growth, cut clean and depend upon advance reproduction.

LOGGING METHODS

Methods now used in the region are permissible if carried out with reasonable care. This includes horse logging and tractor logging with arches, wheels, pans, and bummers.	The same methods may be used that are permissible under minimum forestry, except that special precautions must be taken to insure less damage and a wider margin of safety.

INSECT CONTROL

Control epidemic insect infestations by cooperation of private and public agencies. Ordinarily little control of fungus diseases justified.	Control epidemic insect infestations. In addition utilize selective cutting to control normal occurrence of beetles by removal of infested trees and trees susceptible to attack. Remove disease spreaders, such as trees badly infected with conk rots and mistletoe.

GRAZING

Regulated grazing like that on national forests. Follow methods of open herding and 1-night use only of bed grounds. Avoid overgrazing. Temporary exclusion of stock to permit establishment of reproduction required only in extreme cases.	Same as for minimum forestry except for additional precautions to insure greater margin of safety in securing reproduction. This may occasionally mean temporary exclusion of stock.

WATERSHED PROTECTION

Minimum measures	Intensive measures
Complete protection of watershed and stream-flow interests. Under average conditions these are adequately safeguarded by the recommended minimum measures for fire protection, cutting, logging, slash disposal, and grazing. In drainages of loose soil and steep slopes, however, additional precautions necessary as follows: Horse and chute logging as against tractors; unqualified use of selective cutting; special grazing restrictions such as reduction in numbers of stock, temporary suspension, or, in severe cases, elimination of range use.	Complete protection as described under minimum measures.

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